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UNIVERSITAT POLITÈCNICA DE CATALUNYA

# TREBALL FI DE CARRERA

**Títol**

**Seabed and scour protection interaction**

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## ABSTRACT

This study treats the removal of sediment from between one and two layers armour blocks on a 1:13 slope. The study is based on experimental data on this purpose. It has been studied spilling, plunging and surging breakers on a 1:13 slope. One mechanism is described depending the ratio between sediment and armour blocks d/D. The governed parameters are, in addition to d/D, the breaking parameter $A = \frac{T^2 g}{H}$ and the mobility number $\Psi = \frac{(H/T)^2}{g(s-1)d}$ where H can be the offshore wave height or the local wave height. Design diagrams for ψ mobility number are given in the case of offshore wave heights and local wave heights. It has also done the comparison of the design diagrams between the slope 1:13 and the slope 1:30 studied earlier. The application of the design diagrams are shown in an example. Finally a briefly part of conclusions is given.

## RESUM

Aquesta investigació tracta de l'extracció de sediment entre una i dues capes de roques com a protecció. Aquesta investigació està basada en dades experimentals obtingudes per a aquest propòsit. Han estat estudiats els trencaments d'ona *spilling, plunging* i *surging* per a una pendent 1:13. Un mecanisme és descrit depenent de la relació entre el tamany del sediment i el de la protecció, d/D. Els paràmetres governants són, a més de d/D, el paràmetre de trencament $A = \frac{T^2 g}{H}$ i el número de mobilitat $\Psi = \frac{(H/T)^2}{g(s-1)d}$ on H pot ser l'altura d'ona offshore (alta mar) o l'altura d'ona local. Són presentats diagrames per al disseny en funció del número de mobilitat tant per altures d'ona offshore com per altures d'ona locals. S'han comparat els diagrames de disseny per una capa i dues capes, per a una pendent 1:13. També s'ha dut a terme la comparació dels diagrames de disseny per una capa de protecció entre les pendent 1:13 i 1:30

(aquesta última estudiada anteriorment). Finalment es mostra una petita part de conclusions.

## PREFACE

This report is a master thesis (tesina in catalan) carried out in the period from the end of September 2008 to the end of June 2009 at the section of Coastal and River Engineering, a part of the Departament of Mechanical Engineering (MEK) at the Techincal University of Denmark (DTU). The report was carried out under supervision of Professor B. Mutlu Sumer and Professor Octavio César Mösso Aranda.

This report is divided into six chapters Firsta short introduction to the problem of suction of sediment in breaking waves. The second chapter is about the experimental setup and the procedures behind the experiments. Chapter three is about the test conditions. Both the conditions and the results are listed in tables. Chapter four leads the reader through the mechanism of suction caused by spilling and plunging breakers on a 1:30 slope. Chapter five is about the dimensionless parameters used in the study and the idea behind them. Finally chapter six gives the design diagrams for critical suction on a 1:13 slope, several comparisons between design diagrams, and a practical example about the application of these design diagrams.

I would like to thank Professor Mutlu Sumer, Professor Octavio César Mösso Aranda and Anders Wedel Nielsen for their guidance and help. Also thanks to the staff in the laboratory for their help and assistance.

# NOMENCLATURE

| | |
|---|---|
| A | wave breaking parameter |
| $c_D$ | drag coefficient |
| D | armour layer stone size, if nothing else noticed $D_{50}$ (the diameter corresponding to 50% of the material being finer) |
| d | particle or sediment diameter, if nothing else noticed $d_{50}$ (the diameter corresponding to 50% of the material being finer) |
| De | Dean Number |
| g | acceleration due to gravity (9.81m/s2) |
| H | wave height |
| $H_0$ | deep water wave height |
| h | water depth |
| $h_0$ | 'deep' water depth |
| $h_{hole}$ | local height in a hole. Measured from base bottom |
| L | wave length |
| $L_0$ | deep water wave length |
| l | local horizontal distance |
| $l_{break}$ | Distance from point of breaking to measurement section |
| $l_{mes}$ | the distance from the beginning of the slope to the measurements section |
| m | mass |
| $m_p$ | mass of particle |
| N | number of waves |
| s | specific gravity of particle or sediment |
| S | distance from beginning of slope to the shore line |
| T | wave period |
| Um | maximum horizontal velocity of wave measured at y = D |
| $w_s$ | fall velocity |
| $\alpha$ | angle of a descending eddy |
| $\beta$ | bed slope angle |
| $\eta$ | local water elevation |

| | |
|---|---|
| $v$ | kinematic viscosity ($10^{-6}$m2/s) |
| $\xi_0$ | surf similarity parameter (or Iribarren number) |
| $\rho$ | density |
| $\sigma$ | standard deviation |
| $\psi$ | Mobility number |
| $\omega$ | angular frequency of waves or descending eddies |

# INDEX

# 1. INTRODUCTION

One of the main objectives in coastal engineering is to avoid the erosion of a sand bed. Included in the term erosion, exists specifically the term scour. The meaning of the term scour is the removal of sand bed (granular bed material) due to the hydrodynamic forces in the proximity of coastal structures. This study will treat the case of the failure of the scour protection due to breaking waves.

Rock dumping is one of the methods widely used for scour protection. The Rock Dumping method has several applications such as: protection of the subsea constructions (mattresses, platforms, pipelines, etc.), levelling of the seabed before installing platforms or pipelines Interesting applications related to this study are the protection of the foundations of a structure built in the surf zone (for example: the piles of a bridge or a windmill) or the protection of a beach at the foot of a cliff.

A type of protection is armour (rock) layers which can be designed in many different forms. The simplest type is one layer of big stones where more layers can be added to improve the effect of the protection.

Regarding the removal of sediment from between armour blocks, some studies have been made. Sumer et al. [2001] investigated the process of suction from a base sediment bed covered by an armour block/stone layer in steady current. It was determined the mechanism responsible for the suction process, critical conditions for the onset of suction and implications for the armour layer. Hatipoglu et al. [2008] made an extension of Sumer's work in the case of waves and combined waves and currents. Nielsen [2004] found the mechanism of removal of sediment from between one layer of armour blocks/stones in the case of breaking waves and made design diagrams for the onset of suction.

The experimental work in this report is a follow up to Nielsen [2004] and it has the objective to study the process of removal of sediment from between one and two layers of armour blocks/stones, to compare the results with the work of Nielsen [2004], and to make design diagrams for the onset of suction considering: one and two layers of armour stones, and two different slopes for the base sediment bed. Dimensionless parameters for sediment mobility and the breaking have been used to carry out the composition of the diagrams.

# 2. EXPERIMENTAL SETUP

## *2.1 The Flume*

All the experimentation was executed in a water flume with the following dimensions: 4m in width, 1m in depth and 34m in length. The effective length of the flume (without wave maker and outlet) is 28m. Waves were generated with a piston type wave maker controlled by DHI Wave Synthesizer with AWACS version 2.15 (Active Wave Absorption Control System). The flume has also the possibility for generation of a current by recirculation of the water. This possibility was not used during these experiments.  The water depth in the experiments was maintained at h=0.40 m. In some cases it was changed to produce the breaking of waves at the same distance from the toe of the slope.

The active wave absorber works in the following way: 3 wave gauges were fixed on 3 girders across the flume. 2 were static and 1 was dynamic. The two statics were placed: one in the offshore and the other one on the toe of the slope. The dynamic one was placed in the surf zone. A calibration was carried out comparing the wave height measured on the gauges with the wave height required by the amplitude wave theory, which of course results in a smaller wave height. If it is too low the flap will move forward, giving a higher wave. For further details about active wave absorption see e.g. Dean and Dalrymple [1984] p 178.

*Figure 2.1: The flume where the experiments have been carried out*

## *2.2 The sloping bed*

The slope was constructed of sand. A big amount of sand was placed in the flume. See figure 2.2. The inclination of the slope was set to be 1:13 which was chosen from the previous study of Nielsen [2008]. That inclination was chosen because it was double steeper than the slope Nielsen used. The toe of the slope was located 8,20 m. after the wave generator.

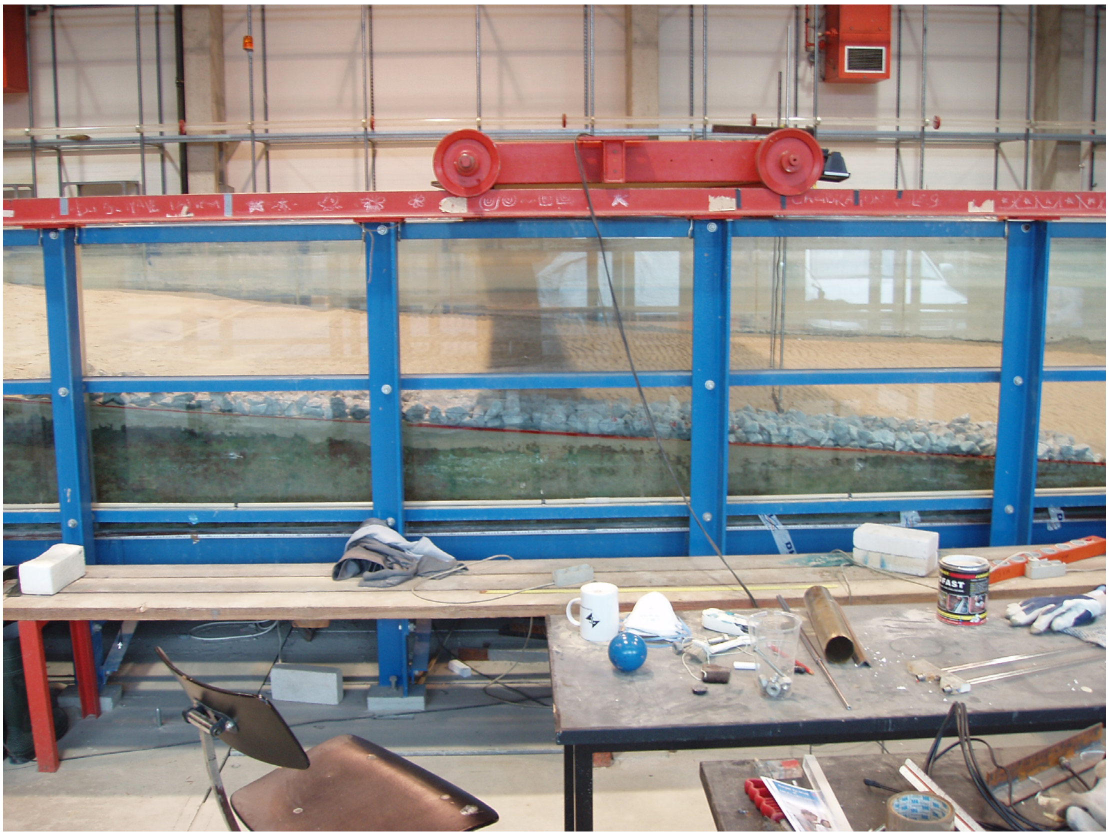


*Figure 2.2: View of sloping bed and two layers of stones ($D_{50}$=4cm)of armour protection*

## *2.3 Wave gauges*

Wave heights were measured with ordinary impedance wave gauges. In order to calibrate the wave gauges, the voltage that was corresponding to a certain level of surface elevation was sampled, thus a relation between the surface elevation and voltage was obtained. For each different case of study, the calibration procedure was repeated. The calibration plots for each of the gauges in each of the sections can be found in Appendix B.

Three wave gauges were used at different locations. Two were static and one was dynamic. The two static gauges were fixed on steel girders across the flume. One of them was placed after the filter and the other was placed above the toe of the slope. The dynamic gauge was fixed in a mobile platform in order to measure the wave height in the breaking wave line for all the tests.

*Figure 2.3: Wave gauge*

## *2.4 Stones for the armour layer*

The stones were placed on the slope and additionally on the box in the case of having different sediment than fine sand. They were placed in an area of 0.5 m wide and between 2 and 3  m length. Three kinds of stones were used:

(1) $D_{50}$= 2.5cm. Crushed stones.

(2) $D_{50}$= 4.0cm. Crushed stones.

(3) $D_{50}$= 8.5cm. Rounded natural stones.

These statistics were obtained from random samples (the size of these samples was 30). In the tests, the stones were laid one-layer deep and two-layer stone cover.

### *2.5 Sediment-Bed Experiments*

Two kinds of sediment-bed experiments were made:

1. The sediment in the first experiments was the same sand that created the slope and the critical condition for suction was studied. See chapter 6.1.

2. The sediment in the second experiments was placed in a box 0.9 m in length, 0.17 m in depth, and about 0.6 m in width. This box was placed in-between the forming-sand slope. The surface of the sediment in the box was flush with the sand slope. The box is shown in figure 2.4.

*Figure 2.4: The box in between the flume sand containing plastic particles ($d_{50}$= 3.80cm)*

Four kinds of different bed sediment were used:

| | |
|---|---|
| (1) Fine sand(flume sand) | $d_{50}$ = 0.17 mm. |
| (2) Single plastic particles | $d_{50}$ = 3.80 mm. |
| (3) Medium sand | $d_{50}$ = 1.40 mm. |
| (4) Thick sand | $d_{50}$ = 2.80 mm. |

The properties of these materials are given in the table 3.1 (chapter 3)

### 2.5.1 Relative density and Specific gravity

The relative gravity, which is a dimensionless parameter,

$$s = \frac{\gamma_s}{\gamma}$$

is the ratio of the specific gravity $\gamma_s$ of the grains and $\gamma$ which is the specific gravity of the water at 4ºC. For sand sediments it is often close to 2.65.

The determination of the specific gravity was carried out by the fall velocity. The particle was dropped in a vertical pipe filled with water and the time of fall was measured. The formula used to calculate the specific gravity was (Fredsøe and Deigaard [1992] p. 199):

$$s = 1 + \frac{3c_D \omega_s^2}{4gd}$$

where the drag coefficient $C_D$ was found in “Schlichting diagram” (Schlichting [1979])

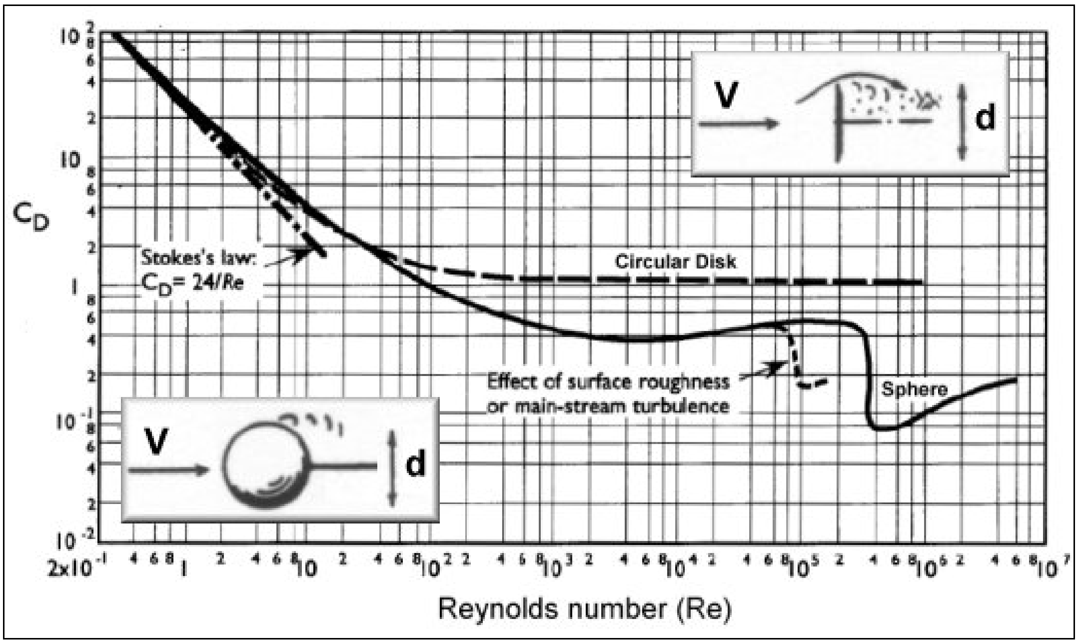



*Figure 2.4: Drag coefficient of a circular disk and a sphere versus Reynolds number. Font: www.aerospaceweb.org*

Reynolds number is defined as: $\mathrm{Re} = \frac{\omega_s d}{\nu}$

For a wide range of values of Re, the drag coefficient can be calculated as:

$$C_D = \frac{24}{\mathrm{Re}} + \frac{6}{1+\sqrt{\mathrm{Re}}} + 0.4$$

### 2.5.2 Particle size. Sieve analysis

The most usual and convenient method for the analysis of particle size distribution is the sieve analysis, which is not applicable for particle sizes smaller than 0.06 mm. In figure 2.8 the grain-size distribution curves for a log-normal grain size distribution are plotted.

*Figure 2.5: Sieve test machine*

*Figure 2.6: Thick sand, medium sand and flume sand*

*Figure 2.7: Precision weight*

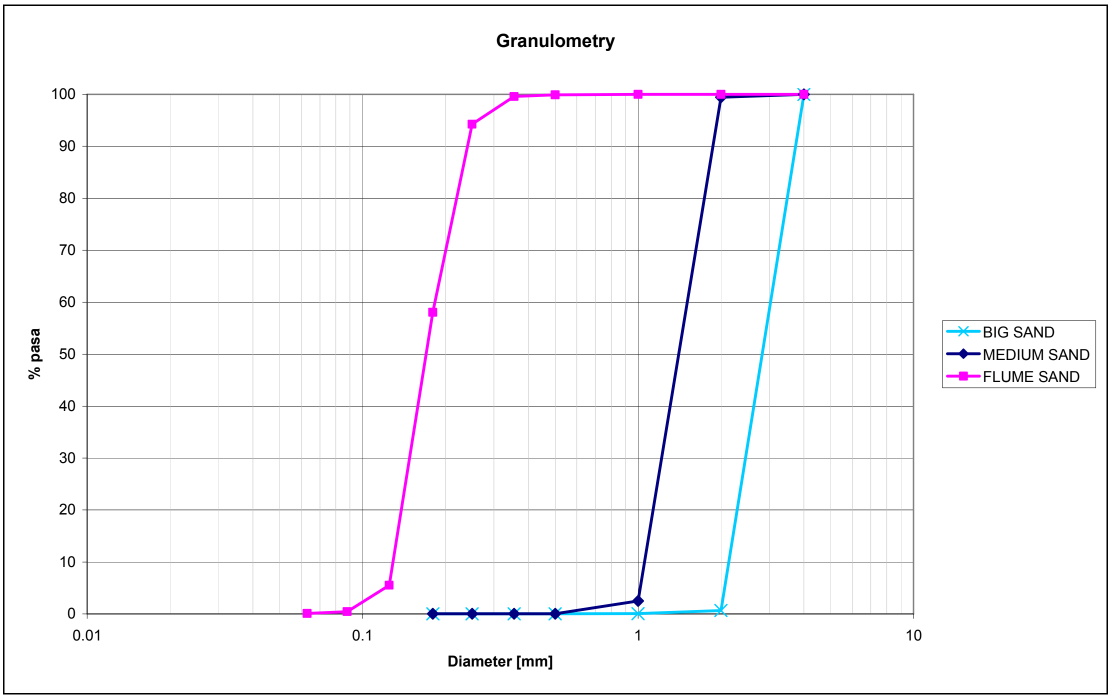



*Figure 2.8: Grain-size distribution for the sediment sand used in the experiments*

# 3. TEST CONDITIONS

The aim of the tests is to find the critical values of wave height *H*, wave period *T* on a fixed water depth *h* that causes suction of the flume sand bed.

## *3.1 Procedure of the tests*

- Set the sediment in the box between the sand of the flume.
- Flat the sand of the flume in the right slope: 1:13
- Set the stones, in one or two layers, on the sediment. 70 cm. x 2.5 m.
- Fill the flume, normally $h_0$ = 40 cm.
- Calibration of the 3 gauges
- Turn on the wave maker
- Run a first regular small wave (low wave height) and a decided wave period to see if it breaks in the section wanted (normally on the box of sediment) for a short period of time.
- Fill up or empty the flume if the waves before don't break on the box of the sediment.
- Mark 3 or 4 holes (depending on the $D_{50}$) with coloured sticks.
- Put the waterproof camera focusing the holes which have been marked.

*Figure 3.1: Waterproof camera and 3 coloured sticks marking the holes to check if there is suction in a two layers of D50=4 cm. stones protection*

- Run a regular wave with a small wave height and with a decided wave period for 2 minutes.
- While the waves are running, check with human eye and with the camera eye, if the sediment is suctioned in between the armour stones layer/s.
- Write if there is suction or not in each of the holes.
- Run again a test but increasing the wave height with the same or very similar wave period.
- When there has been suction in all the holes, the test is finished.

Table 3.1 contains the results of the **critical suction experiments**. Appendix A contains all the tests carried out.

*Table 3.1: Results of the suction tests experiments (continuation)*

| TEST INFORMATION | | | | STONES | | | SEDIMENT | | | | | | FLOW PROPERTIES | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test Number | Case number | number of holes to study per section | holes with suction | D [cm] | Number of layers | Material | $d_{50}$ [cm] | $s=\rho_s/\rho$ | $w_s$ [cm/s] | Material | Single/Sediment | d/D | $h_0$ [cm] | $H_{in}$ [m] | $H_0$ [cm] | $H_{mes}$[cm] |
| 1 | 1 | 4 | 4 | 2.5 | 1 | Crushed Stones | 0.3 | 2.65 | 23.3 | Sand | Sediment | 0.12 | 366.875 | 0.0638 | 34.779 | 54.632 |
| 2 | 1 | 4 | 4 | 2.5 | 1 | Crushed Stones | 0.3 | 2.65 | 23.3 | Sand | Sediment | 0.12 | 36.125 | 0.0588 | 53.612 | 7.66 |
| 3 | 1 | 4 | 4 | 2.5 | 1 | Crushed Stones | 0.3 | 2.65 | 23.3 | Sand | Sediment | 0.12 | 348.125 | 0.0875 | 65.383 | 70.643 |
| 4 | 2 | 4 | 4 | 2.5 | 1 | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.056 | 373.125 | 0.0475 | 33.458 | 51.846 |
| 5 | 2 | 4 | 4 | 2.5 | 1 | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.056 | 36 | 0.04 | 35.337 | 31.859 |
| 6 | 2 | 4 | 4 | 2.5 | 1 | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.056 | 36.125 | 0.0419 | 3.28 | 39.689 |
| 7 | 3 | 4 | 4 | 4 | 2 of 2.5 cm | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.035 | 380.625 | 0.0837 | 44.988 | 73.786 |
| 8 | 3 | 4 | 4 | 4 | 2 of 2.5 cm | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.035 | 38.625 | 0.0775 | 67.722 | 76.661 |
| 9 | 3 | 4 | 4 | 4 | 2 of 2.5 cm | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.035 | 39.25 | 0.1294 | 103.369 | 66.443 |
| 10 | 4 | 4 | 4 | 7.5 | 2 of 4.0 cm | Crushed Stones | 0.38 | 1.39 | 11.3 | Plastic | Single | 0.0507 | 38.5 | 0.0575 | 44.016 | 53.343 |
| 11 | 4 | 4 | 4 | 7.5 | 2 of 4.0 cm | Crushed Stones | 0.38 | 1.39 | 11.3 | Plastic | Single | 0.0507 | 38 | 0.0581 | 46.976 | 5.092 |
| 12 | 5 | 4 | 4 | 4 | 1 | Crushed Stones | 0.3 | 2.65 | 23.3 | Sand | Sediment | 0.075 | 38.75 | 0.0837 | 62.676 | 62.881 |
| 13 | 5 | 4 | 4 | 4 | 1 | Crushed Stones | 0.3 | 2.65 | 23.3 | Sand | Sediment | 0.075 | 38.875 | 0.0925 | 8.167 | 82.274 |
| 14 | 5 | 4 | 4 | 4 | 1 | Crushed Stones | 0.3 | 2.65 | 23.3 | Sand | Sediment | 0.075 | 37 | 0.085 | 67.728 | 56.585 |
| 15 | 6 | 4 | 4 | 4 | 1 | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.035 | 37.25 | 0.0412 | 39.393 | 33.465 |
| 16 | 6 | 4 | 4 | 4 | 1 | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.035 | 36 | 0.04 | 28.882 | 45.652 |
| 17 | 6 | 4 | 4 | 4 | 1 | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.035 | 36.5 | 0.075 | 52.837 | 55.406 |
| 18 | 7 | 4 | 4 | 7.5 | 2 of 4.0 cm | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.0187 | 394.375 | 0.09 | 64.588 | 8.748 |
| 19 | 7 | 4 | 4 | 7.5 | 2 of 4.0 cm | Crushed Stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.0187 | 39.125 | 0.1375 | 132.717 | 83.956 |
| 20 | 8 | 3 | 3 | 8.5 | 1 | Rounded stones | 0.38 | 1.39 | 11.3 | Plastic | Single | 0.0447 | 391.667 | 0.0433 | 39.413 | 3.468 |
| 21 | 9 | 3 | 1 | 8.5 | 1 | Rounded stones | 0.3 | 2.65 | 23.3 | Sand | Sediment | 0.0353 | 41 | 0.1 | 81.345 | 81.569 |
| 22 | 9 | 3 | 3 | 8.5 | 1 | Rounded stones | 0.3 | 2.65 | 23.3 | Sand | Sediment | 0.0353 | 39.5 | 0.08 | 59.409 | 88.306 |
| 23 | 10 | 3 | 3 | 8.5 | 1 | Rounded stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.0165 | 420.333 | 0.1117 | 91.443 | 7.026 |
| 24 | 10 | 3 | 3 | 8.5 | 1 | Rounded stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.0165 | 38.4 | 0.05 | 34.471 | 54.961 |
| 25 | 10 | 3 | 3 | 8.5 | 1 | Rounded stones | 0.14 | 2.65 | 16 | Sand | Sediment | 0.0165 | 38.4 | 0.045 | 56.275 | 54.568 |

*Table 3.1: Results of the suction tests experiments*

| FLOW PROPERTIES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| T [s] | $\psi_0$ | $\psi_{mes}$ | $A_0$ | $A_{mes}$ | $\sigma\psi_0$ | $L_{mes}$ [m] | $L_0$ [m] | $\xi_0$ | Type of breaking |
| 54.625 | 0.0008 | 0.0021 | 84.339.026 | 54.503.574 | 0.0001 | 4.37 | 46.588 | 3.51 | Surging |
| 3.375 | 0.0052 | 0.0107 | 20.880.036 | 14.953.752 | 0.0001 | 4.25 | 17.784 | 2.26 | Plunging |
| 14.125 | 0.0443 | 0.0523 | 2.996.324 | 2.783.285 | 0.0018 | 4.1 | 3.115 | 0.78 | Plunging |
| 5.15 | 0.0019 | 0.0048 | 79.925.768 | 55.409.022 | 0.0007 | 4.35 | 41.410 | 3.84 | Surging |
| 3 | 0.0063 | 0.0054 | 26.059.788 | 30.592.386 | 0.0013 | 4.275 | 14.052 | 2.44 | Surging |
| 1.1 | 0.0391 | 0.0577 | 3.653.594 | 3.102.916 | 0.0089 | 4.1 | 1.889 | 0.87 | Plunging |
| 55.125 | 0.003 | 0.008 | 68.289.918 | 40.909.982 | 0.0009 | 4.37 | 47.445 | 3.10 | Surging |
| 33.875 | 0.0178 | 0.0226 | 1.667.462 | 14.772.073 | 0.0017 | 4.3 | 17.916 | 1.98 | Plunging |
| 1.1 | 0.3956 | 0.1622 | 1.165.573 | 1.801.427 | 0.1057 | 4.1 | 1.889 | 0.50 | Plunging |
| 2.575 | 0.0211 | 0.042 | 14.716.714 | 10.523.893 | 0.0052 | 4.3 | 10.352 | 1.74 | Plunging |
| 1.2 | 0.1378 | 0.1374 | 2.687.531 | 2.697.739 | 0.0393 | 4.2 | 2.248 | 0.81 | Plunging |
| 1.275 | 0.0548 | 0.0513 | 2.989.128 | 2.600.531 | 0.0167 | 4.4 | 2.538 | 0.72 | Plunging |
| 3.375 | 0.0122 | 0.0126 | 13.791.434 | 13.936.188 | 0.001 | 4.4 | 17.784 | 1.80 | Plunging |
| 5.1 | 0.0037 | 0.0025 | 3.799.788 | 45.242.444 | 0.0007 | 4.24 | 40.610 | 2.84 | Surging |
| 49.875 | 0.0029 | 0.0021 | 63.740.641 | 79.617.121 | 0.001 | 4.32 | 38.838 | 3.99 | Surging |
| 3 | 0.0043 | 0.0107 | 32.133.908 | 20.292.024 | 0.0015 | 4.28 | 14.052 | 2.44 | Surging |
| 1.1 | 0.1071 | 0.1141 | 2.378.593 | 2.192.937 | 0.0523 | 4.1 | 1.889 | 0.65 | Plunging |
| 51.125 | 0.0071 | 0.013 | 40.028.778 | 2.951.089 | 0.001 | 4.32 | 40.809 | 2.77 | Surging |
| 3 | 0.0873 | 0.0347 | 6.734.185 | 10.551.895 | 0.0171 | 4.12 | 14.052 | 1.31 | Plunging |
| 1.5 | 0.1094 | 0.0845 | 2.544.025 | 2.898.198 | 0.0305 | 4.34 | 3.513 | 1.17 | Plunging |
| 2.5 | 0.0055 | 0.0055 | 3.038.791 | 30.072.963 | 0 | 4.3 | 9.758 | 1.28 | Plunging |
| 3 | 0.0085 | 0.0186 | 15.650.919 | 10.452.262 | 0.0038 | 4.2 | 14.052 | 1.72 | Plunging |
| 1.625 | 0.2726 | 0.1618 | 1.483.459 | 1.913.594 | 0.0638 | 42.767 | 4.123 | 0.79 | Plunging |
| 3 | 0.0062 | 0.0154 | 28.478.167 | 1.693.032 | 0.0024 | 4.25 | 14.052 | 2.18 | Surging |
| 4.5 | 0.0057 | 0.0053 | 44.948.138 | 45.375.323 | 0.0018 | 4.25 | 31.617 | 3.45 | Surging |

*Table 3.1: Results of the suction tests experiments*

# 4. THE MECHANISM OF REMOVAL OF SEDIMENT UNDER BREAKING WAVES

In order to describe the mechanism of removal of sediment, Nielsen's [2004] investigation for the mechanism of removal of sediment in the case of one armour stones layer will be shown.

In Nielsen [2004], a visualisation of the flow with different techniques was done. A detailed resume of the results are next shown.

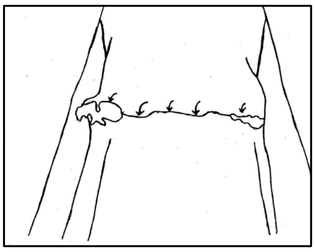
The experimentation was done in a flume with the following dimensions: 34 m long, 0.6 m wide and 0.8 m deep.

## *4.1 The 1:30 slope*

On the 1:30 slope it was possible to generate spilling and plunging breakers. The main difference between both breakers is the power of breaking. The plunging breaker is more powerful than the spilling breaker, especially in the beginning of the breaking process.

The plunging breaker process for T=3.0s and H=14.5cm:

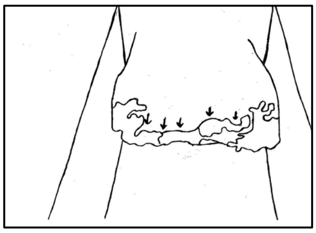
1



Just before the breaking. Small undulations can be seen at the wave front

ωΔt = 0.0º

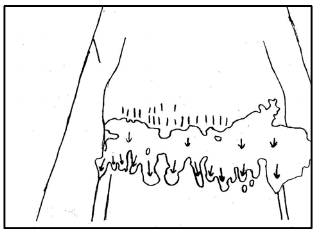
2



The wave starts the break.

ωΔt = 9.6º

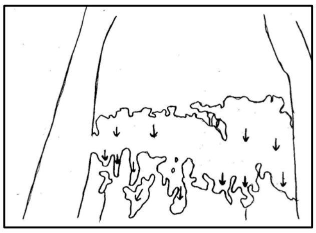
3



A number of “fingers” are sticking out from the bore. These are part of the wave crest. The fingers have moved faster than the rest of the wave crest.

ωΔt = 24.0º

4



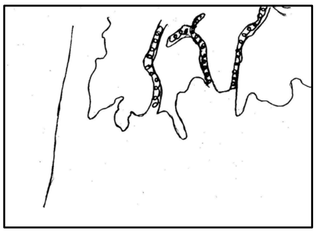
$\omega\Delta t = 33.6^{\circ}$

5

$\omega\Delta t = 67.2^{\circ}$

The “fingers” get bigger (4) and in (5) the rest of the wave finally breaks.

6

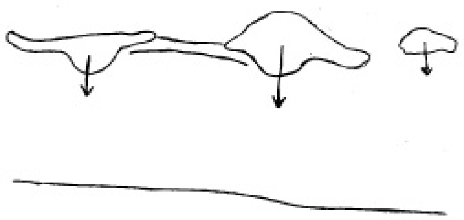


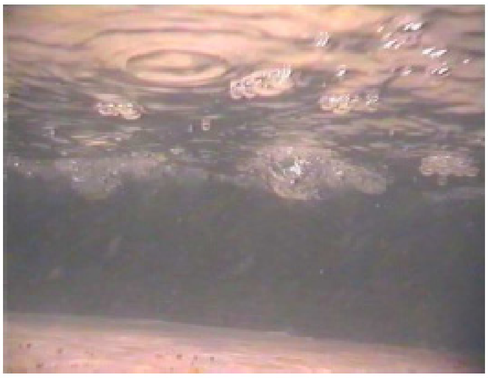
$\omega\Delta t = 105.6^{\circ}$

The wave is nearly passed but a number of descending eddies can be seen (the dark “tubes” of bubbles).

## *4.2 Descending eddies*

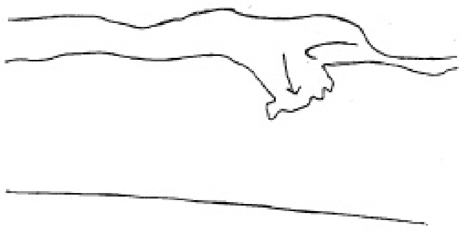
As the descending eddies can be watched underwater to understand their generation, visualization underwater was done with the results shown in the figure 4.1.

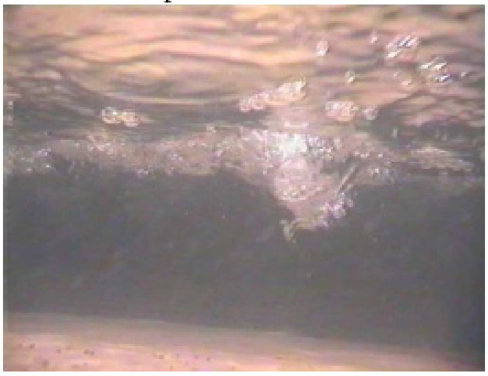




$\omega\Delta t = 0.0^\circ$

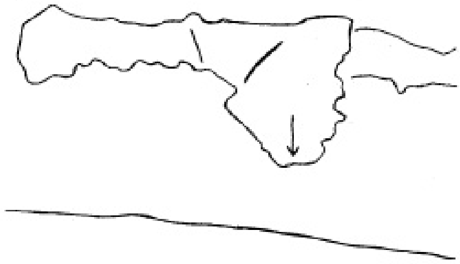
Snapshot $\omega\Delta t = 0.0^\circ$

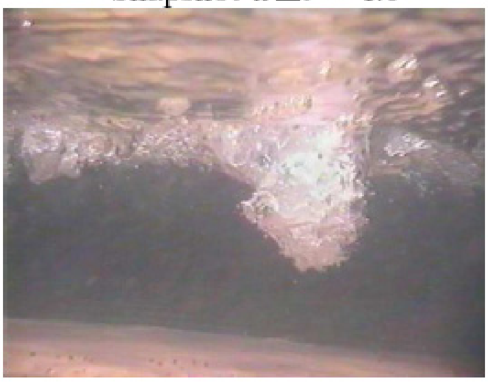




$\omega\Delta t = 4.8^\circ$

Snapshot $\omega\Delta t = 4.8^\circ$





$\omega\Delta t = 9.6^\circ$

Snapshot $\omega\Delta t = 9.6^\circ$

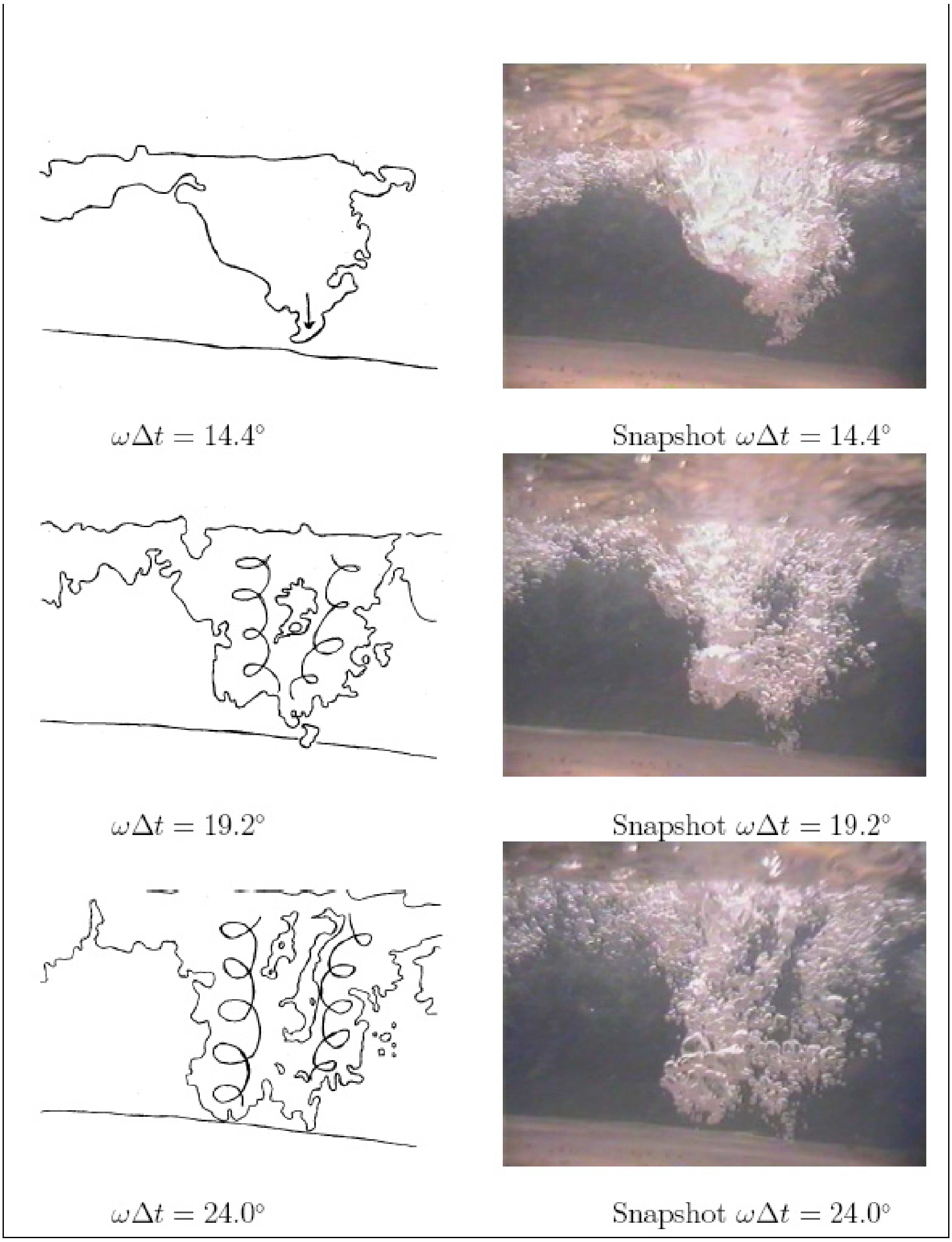



*Figure 4.1. The generation of a descending eddy. The camera is fixed and the direction is offshore. Wave conditions: T=3.0 s and H=12.9 cm.*

At the $\omega\Delta t = 0.0^{o}$ the finger has penetrated the surface. The finger continues down, but because of the velocity difference between the finger and the main body of water, the wave breaks. This will of course generate shear stresses, which will cause a bended eddy surrounding the finger. Because of the friction near the bed and the shape bend, the connection between the sides of the finger gets destroyed. Then the finger ends up either with two eddies rotating in opposite directions or with a pair of oblique descending eddies (see the last two frames).

During the investigation of the breaking wave, Nadaoka et al. [1989] measured the flow in front of the bore. These measurements show that the flow was backward when the bore was moving forward. When the finger penetrates the surface it will move with the velocity of the bore and then accelerate to the velocity of the main body. Because of the opposite flow directions, the eddies in a pair will rotate away from each other as shown on figure 4.3.

Nadaoka et al. [1989] also described that the breaking generated a series of horizontal eddies in the turbulent bore of the wave. These eddies acts like sub-waves and breaks in the same manner, which create new descending eddies, which explain that descending eddies of decreasing strength can be observed from a little after the breaking point to the swash zone.

A series of videos have been made from the breaking point and 1.4 m onshore, in order to see the development in the mechanism of removal. The result of these tests can be seen on figure 4.4, 4.5 and 4.6. Figure 4.4 shows the situation just after breaking. In this section the suction mechanism is the same as under non-breaking wave, described by Hatipoglu et al. [2008].

In the next section the breaking has generated turbulence still not reached before t = 0.88 s, where it causes some weak suction in the left side of the picture. On the other hand is the power of the non-breaking mechanism decreasing due to the decreasing wave height and pressure.

In the last section, see figure 4.6, is the absolute most important mechanisms that one’s leaded by the descending eddies. The mechanism for non-breaking waves will still have an influence, because of the pressure gradient, but it is really weak and will in most cases not result in any suction.

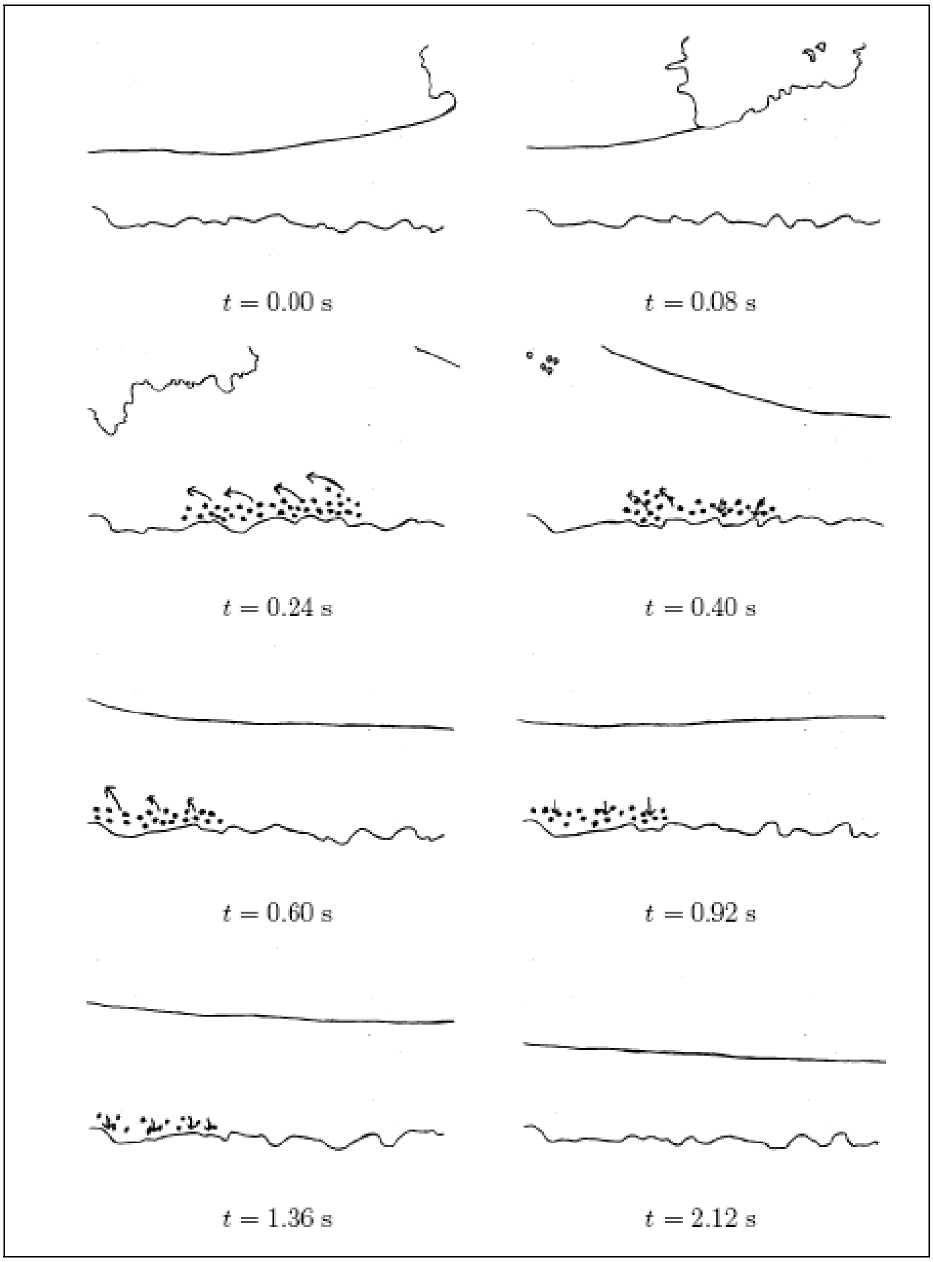



*Figure 4.4: The breaking process 3.4 m to 3.75 m from the beginning of the slope. The wave conditions were T = 4:5 s and H = 13:9 cm.*

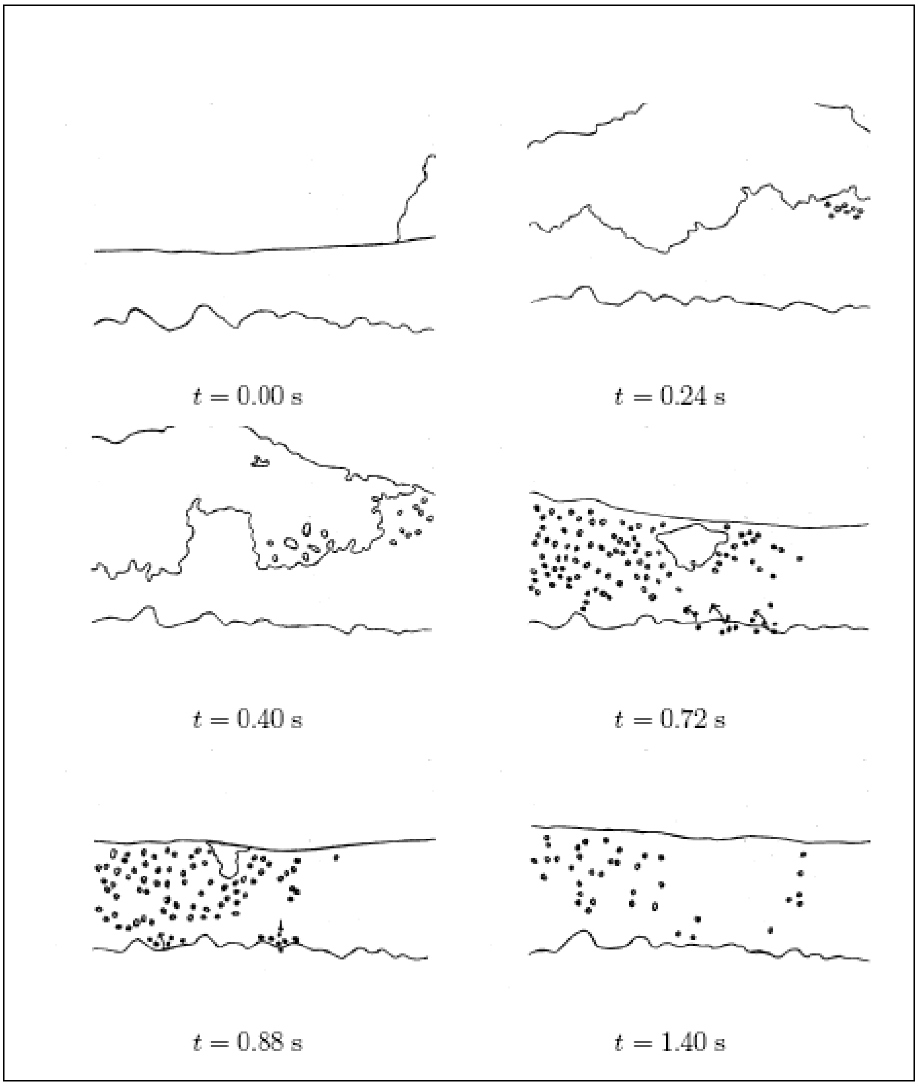



*Figure 4.5: The breaking process 3.95 m to 4.35 m from the beginning of the slope. The wave conditions were T = 4:5 s and H = 13:9 cm.*

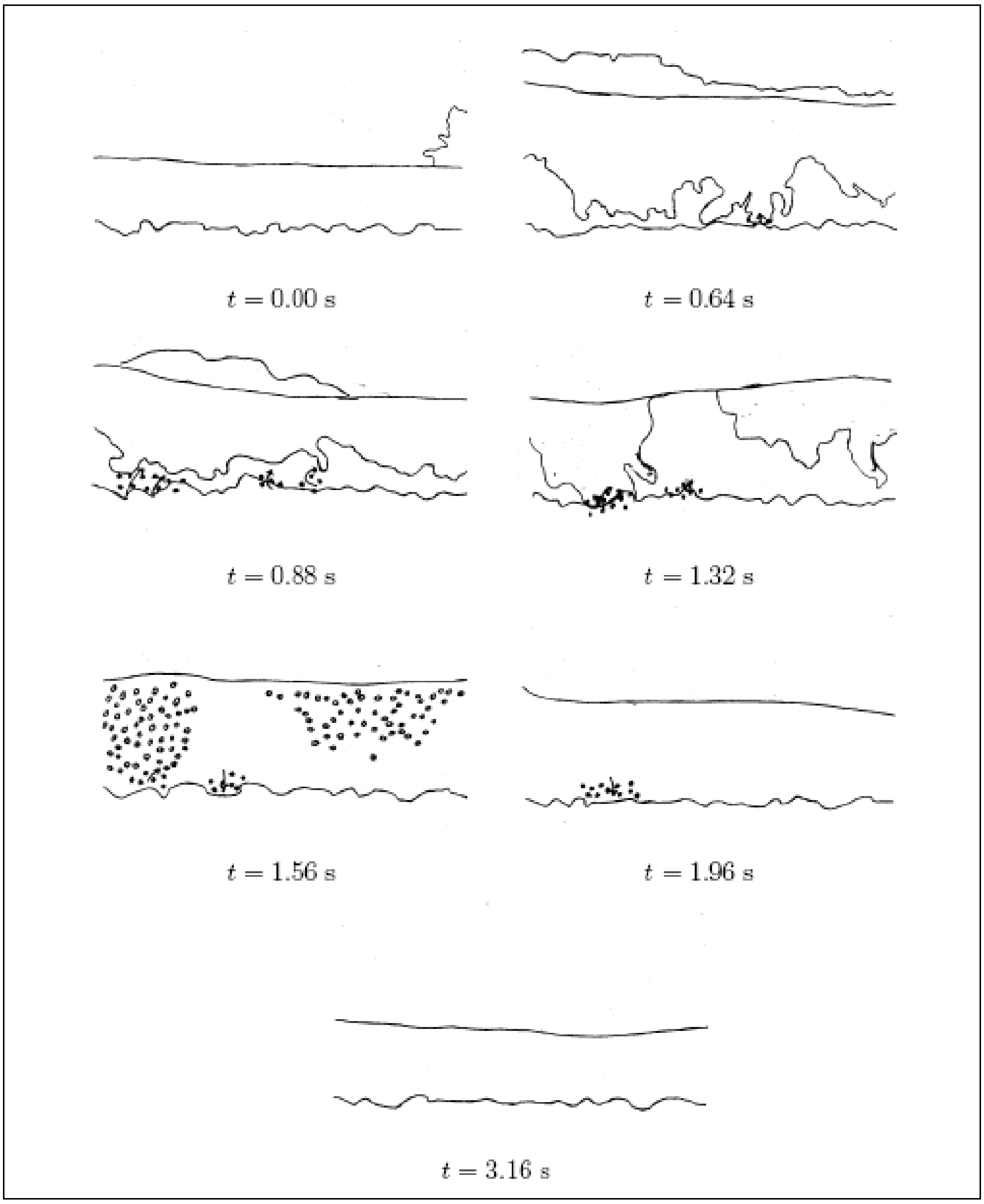



*Figure 4.6: The breaking process 4.50 m to 4.80 m from the beginning of the slope. The wave conditions were T = 4:5 s and H = 13:9 cm*.

## *4.3 The mechanism of removal of sediment*

The conclusion of these experiments is that the mechanism of removal changes during the breaking process.

Just at the breaking point, the mechanism is very similar to that one under non-breaking waves, where the removal is equal under the crest and trough (sinusoidal waves) described by Hatipoglu et al. [2008]. But because of the asymmetry of the wave, the suction under the crest is more powerful than the suction under the trough. The asymmetry is going to be even more dominant further onshore (Davidsen [2003]). This mechanism becomes secondary at a certain point where the turbulence due to the breaking reaches the bed. At this point the obliquely descending eddies (or just descending eddies) described by Nadaoka et al. [1989] take over as the most important mechanism of the suction of sediment under a protection layer. (Davidsen [2003]).

## *4.4 A detailed description of removal of fine sediment (d/D < 0.08): The swirling mechanism*

A series of combined video and velocity measurements were made, in order to find a relation between turbulence and suction and to determine the mechanism of suction of fine material. The tests were carried out approximately 1.6 m from the breaking point. Accordingly to Deigaard et al. [1991] this is sufficiently far away from the breaking point, where the descending eddies have reached the bed.

Two waves were used: One with period T = 1.6 s (spilling breaker) and one with period T =  4.5 s (plunging breaker). Crushed burned clay was used as sediment. The properties of this material is $d_{50}$ = 1.8 mm with a standard deviation of $\sigma$ = 2.65. The specific gravity is s = 1.35 and the fall velocity $\omega_s$ = 7.1 cm/s. For further details see table 4.1.2. The results for $l_{hole}$ = 0.7 cm and $l_{hole}$ = 2.3 cm gave similar results.

| T[s] | $H_0$ [cm] | $H_{mes}$[cm] | $l_{hole}$[cm] | $h_{bed}$ [cm] |
|---|---|---|---|---|
| 1.6 | 14.2 | 12.4 | 0.7 | 4.5 |
| 4.5 | 14.4 | 14.3 | 0.7 | 4.5 |
| 1.6 | 14.0 | 12.2 | 1.5 | 4.5 |
| 4.5 | 14.2 | 15.5 | 1.5 | 4.5 |
| 1.6 | 14.0 | 12.3 | 2.3 | 4.5 |
| 4.5 | 14.4 | 14.3 | 2.3 | 4.5 |

*Table 4.1: Combined laser measurements and video recording. $l_{hole}$ is the distanced from the offshore side of the hole and $h_{bed}$ is the height over the bed.*

By comparing the combined velocity measurements and video records a clear correlation between the arrival of air bubbles, sediment entrainment, and turbulence in the velocity measurements is seen.

When a descending eddy hits the hole, it causes some rather large influence fluctuations in the horizontal and vertical directions, as seen on figure 4.7 and 4.8. It may be noticed that the turbulence is much stronger in case of a plunging breaker compared with a spilling breaker (around 50º) and stopping before as well (around 90º). For the spilling breaker the turbulence starts relatively late (100º), but exists until a new wave passes. These small differences are not changing the fact that the processes are the same in the two cases. The $\omega t = 0º$ is defined as the time t where the up crossing wave passes still water level.

## *4.5 The effect of the descending eddies on entrainment*

The descending eddy is rotating around its own centre axis. When the space is limited like in the hole, the centrifugal force caused by this rotation will generate a secondary current: The water flows upward in the middle of the hole and down again along sides, if the eddy is strong enough this secondary current will be so strong that it will bring up the sediment, which will be exposed for the main body of the water and transported away. The reason why the sediment is transported up along the offshore side of the hole is inclination of the descending eddy.

This effect is the same as seen in river bends. The water level in river bends is deepest in the outside part of the bend and lowest in the inside, because the secondary current transports the sediment to the inside of the bend. An even better analogy is the effect seen when stirring for example a cup of tea: If you stir gently tea leaves and other small particles will be transported to the middle of the cup. By stirring faster the particles can be brought into suspension and raise to the surface where they are transported to the sides (no main flow to take them away) and fall down again and so on.

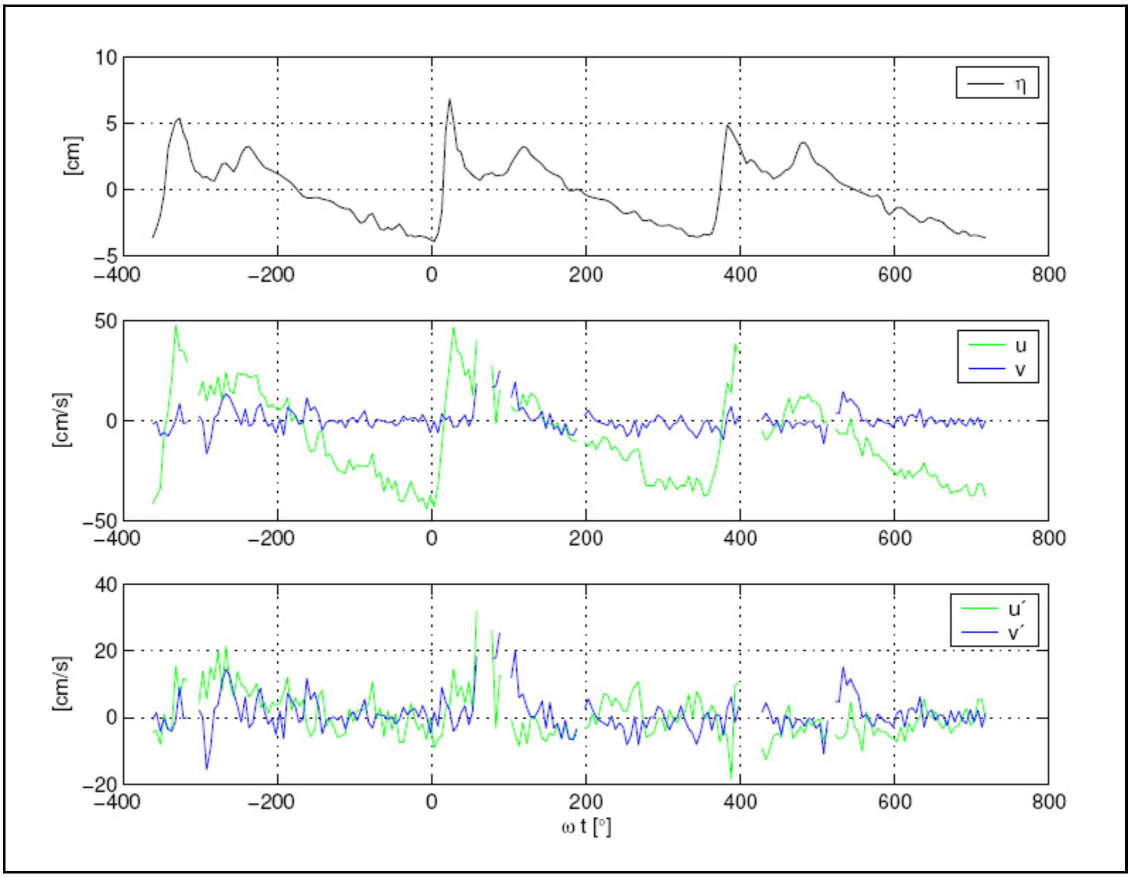



*Figure 4.7: Time series for a plunging breaker (T = 4.5 s and H = 14.2 cm).*

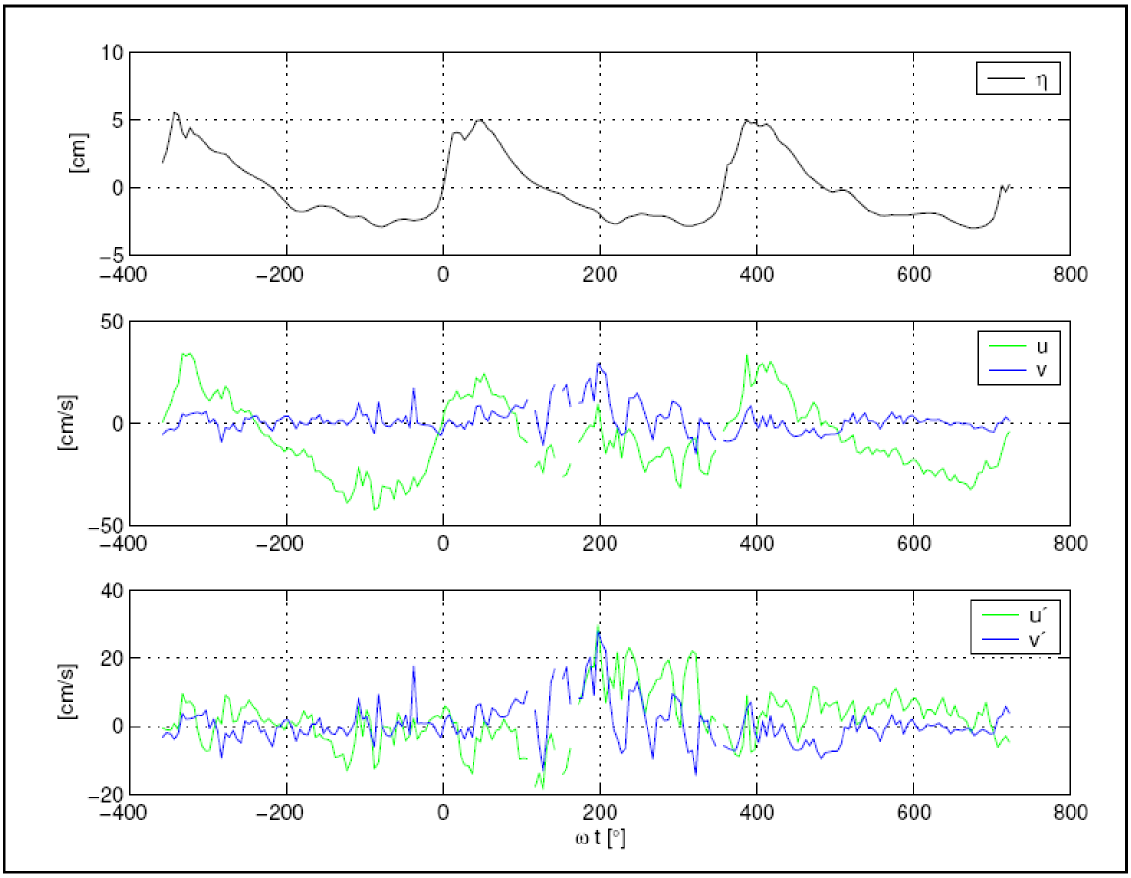



*Figure 4.8: Time series for a spilling breaker (T = 4.5 s and H = 14.2 cm).*

# 5. GOVERNING PARAMETERS

## *5.1 The sediment parameters* **ψ** *and* **De**

The initiation of sediment motion is a discussed theme of investigation. It is difficult to deal with because in the nature, this process depends on a wide range of complicating variables. For example, the sand bed is never perfectly smooth from previous events.

The initiation of sediment motion can be controlled with two different dimensionless parameters in the case of breaking waves: The mobility number and the Dean number. Many different definitions of mobility number can be found depending on the case of study. The case of this study is the removal of sediment in breaking waves.

The mobility number represents the ratio of two forces $F_A/F_R$, in which $F_A$=agitating force that sucks the sediment out of the hole, while $F_R$=resistance force that opposes it. $F_A$=sum of the following forces:

- Vertical pressure-gradient force that causes the entrainment of the water in the "cavities" between the stones
- Drag force in the vertical direction (the drag exerted on the sediment particle by the water, as the sediment particle is carried by the entrained water).
- All other agitating forces

The mobility number for breaking waves is defined by Nielsen [2004]:

$$\Psi = \frac{(H/T)^2}{g(s-1)d}$$

This definition of the mobility number is an adaptation for the breaking wave's case. It is modified from the definition of the mobility number used in the previous works for the cases of non-breaking waves and currents (e.g. Hatipoglu et al. [2008] and Sumer et al. [2001]).

Instead of using *(H/T)*$^2$ in the two other works is used $U_m^2$. $U_m$ = maximum value of the orbital velocity corresponding to the crest half-period measured at y=D from the top of the stones. In breaking waves it is very difficult to determine $U_m$.

The Dean number (Dean [1973]) is defined as:

$$De = \frac{H}{T\omega_s}$$

where $\omega_s$ is the fall velocity of sand particle.

The fall velocity $\omega_s$ depends mainly on the specific gravity, grain size, shape and the dynamic viscosity of the fluid. Particularly, the fall velocity for a spherical shape is:

$$\omega_s = \sqrt{\frac{4g(s-1)d}{3c_D}}$$

Where $c_D$ is the dimensionless drag coefficient

Consequently, the Dean number can be rewritten as:

$$De = \frac{H}{T\sqrt{\frac{4g(s-1)d}{3c_D}}}$$

It can be observed that the difference between the two numbers (Mobility Number and Dean Number) is only that the squared Dean Number is proportional to the mobility number by the drag coefficient.

So, it can be shown how the modification of the mobility number for the case of breaking waves is found:

$$De^2 = \left(\frac{H}{T\omega_s}\right)^2 = \left(\frac{H^2}{T^2\,\frac{4g(s-1)d}{3c_D}}\right) = \frac{3}{4}c_D\,\frac{(H/T)^2}{g(s-1)d} \propto c_D\,\frac{(H/T)^2}{g(s-1)d}$$

### 5.1.1 Comments about Ψ (mobility number)

Regarding the measure of the particle size of the sediment, the mobility number uses the spherical diameter $d_v$, defined as the diameter of a sphere with the same volume of the particle. So, the problem is that $d_v$ ignores the shape of the grains.

The only case in which the mobility number Ψ takes the shape of the sediment grains into account is when the so called fall diameter $d_f$ is used.

The fall diameter (Fredsøe and Deigaard [1992]) is the diameter of a sphere which has the same fall velocity and geomechanic properties in water at 24ºC.

For example, a particle with a certain volume will have a smaller $d_f$ for rounded shaped grains than for angular shaped grains.

This is the case where the Dean number is equivalent to the mobility number, because the Dean number is calculated by the fall velocity.

This problem has not important influence in the case of small sand grains sediments because they have very regular simple shapes, such as spheres or cubes.

When the size of the sand grains is bigger than approximately ($d=O(1mm)$), some grains may have adopted complex shapes, such as flat shape, and it may have a considerable influence into the calculus of the mobility number.

In this study only three different sizes of sand and cylindrical single particles have been used as sediment.

## *5.2 The breaking parameter A*

### 5.2.1 Breaking waves

The wave breaking is related with a transformation of energy from the wave energy to turbulence and to heat. In the surf zone, the sediment transport is very notable. The turbulence due to the wave-breaking jointly with the shallow water produces an agitation and recirculation of the sediment from the bed.

When waves are arriving to shallower water, their wave height increases until they can not increase more and they collapse (the wave breaks). The relation between water depth and wave height on a constant sloping bed is $h \approx 0.8H$.

The waves break because their steepness becomes very large as the depth becomes shallower. Due to the strong energy dissipation, the wave height decreases towards the shore in the surf zone.

### 5.2.2 Type of breaking

The breaking waves can be classified into several different types depending on the wave steepness and the slope. Galvin found a relationship between these two parameters to differentiate between the 3 most import breaking waves types:

$$\xi_0 = \frac{\tan \beta}{\sqrt{\frac{H_0}{L_0}}}$$

The wave height $H_0$ is measured at the toe of the slope and

$$L_0 = gT^2/2\pi$$

From Galvin's experimental data:

| | |
|---|---|
| Spilling breakers: | $\xi_0 < 0.5$ |
| Plunging breakers: | $0.5 < \xi_0 < 3.3$ |
| Surging breakers: | $3.3 < \xi_0$ |

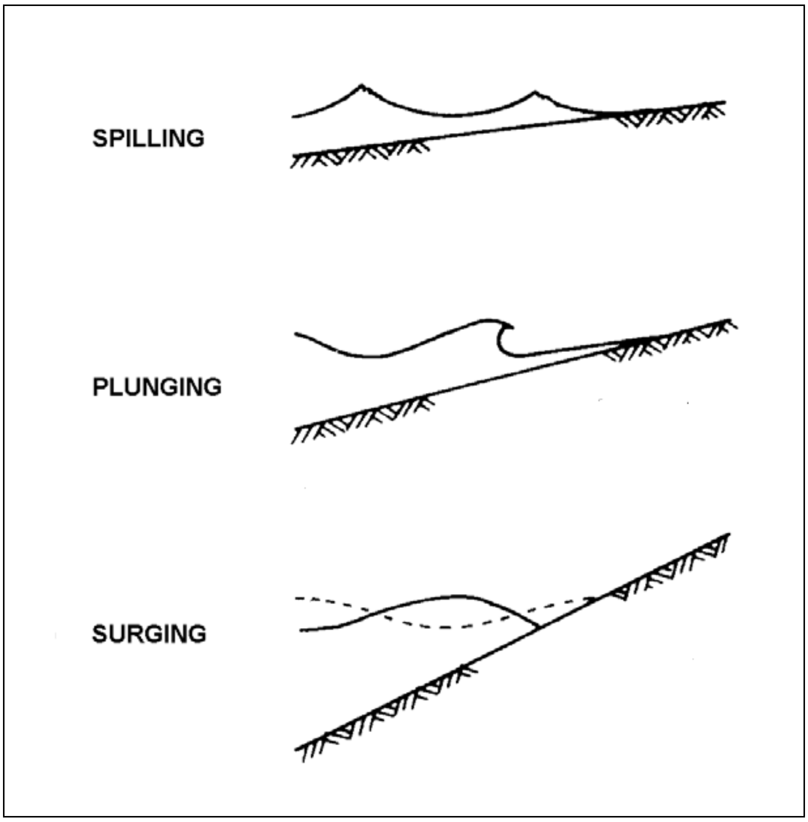



*Figure 5.1. Types of breaking waves. Font: http://www.liv.ac.uk/~ec22/topics/hedges.html*

The Galvin classification is equivalent to the 'surf similarity parameter' or the Iribarren number.

$$N_I = \xi_0 = \frac{\tan\beta}{\sqrt{H / L_0}}$$

The wave height H is measured at the toe of the slope and

$$L_0 = gT^2/2\pi$$

In the case of a slope of 1:13, the only type of breaking waves observed was the plunging breaker. In Nielsen's [2004] data where a slope of 1:30 was used, two kinds of wave breakers were observed: the plunging breaker and the spilling breaker.

The plunging breaker is characterized by the fact that the crest of the wave curls right over the forward face. The impact of the curled mass of water (also called jet) generates a large turbulence and creates large vortices, which can reach the bottom and cause scour.

In the spilling type, the crest spills down the forward face. It can also be observed in figure 5.1 that the slope is very flat for the spilling breakers, while it gets steeper for plunging breakers (and very steep in the case of surging breakers).

### 5.2.3 Intensity of breaking

Each type of breaking can have different intensities of breaking and for this reason it is important to define a parameter, which gives information about the grade of intensity of the breaking.

In a plunging breaker it can be seen (Sumer and Fredsøe [2002]) that the scour depends principally on the following properties:

- The velocity of the penetrating curled mass of water of the plunging breaker at the point of entrance to the main body of water

- The size (distance unit) of the amount of the penetrating water (the falling jet) at the point of entrance to the main body of the water.

- The distance of penetration. In this case the water depth.

Given the breakwater and the sediment, and for critical removal sediment conditions (mobility number $\Psi > \Psi_{cr}$ critical mobility number) the scour will depend only on the dimensionless parameter:

$$\frac{T\sqrt{gH}}{h}$$

If a small analysis of the parameter is done, it can be seen that for a larger numerator of the parameter, the scour is deeper (the parameter is larger).

If the water depth $h_o$ is larger (the value of the breaking parameter will be smaller), it will be more difficult for the penetrating mass of water (the jet) and to reach the bottom. Consequently it will be more difficult to generate recirculation of the sediment (the scour).

This parameter is a simple model of the really complicated breaking process, where the water is not falling like a jet, but is generating descending eddies, see section 4.1. The analogy seems to work anyway because the production of turbulent energy is proportional to the energy of the “falling jet”.

The modification from the breaking parameter defined by Sumer and Fredsøe [2002] done by Nielsen [2004] is the substitution of the water depth for its proportional relation to the wave height for constant sloping beds: $h \approx 0.8H$

Therefore, the A parameter (Intensity of breaking parameter) will be defined as:

$$\frac{T\sqrt{gH}}{h} = \frac{T\sqrt{gH}}{h} \Leftrightarrow \frac{T^2 gH}{(0.8H)^2} = \frac{T^2 gH}{0.8^2 H^2} \Leftrightarrow \frac{T^2 gH}{(0.8H)^2} = \frac{T^2 g}{0.8^2 H} \Leftrightarrow \frac{T^2 g}{0.8^2 H} \propto \frac{T^2 g}{H}$$

$$\boxed{A = \frac{T^2 g}{H}}$$

It must be noticed that the A parameter is also a dimensionless parameter.

# 6 ONSET OF SUCTION

The aim of this part of the experiment is to determine the critical mobility number, where suction begins to occur, for different sizes of particles and sediments.

## *6.1 First Calculations Case Zero*

A first overview of which values of the wave parameters and mobility number of sediment can cause suction of the seabed sediment in the surf zone can be extracted with a preliminary analysis calculation. The first case consists on:

Slope 1:13
One armour layer stone size: 4 cm.
Sediment diameter: 0.02 cm.
Specific gravity of sediment:  2.65

The breaking parameter *A* and $\Psi_0$ (mobility number) have been calculated for several wave heights and periods. Three tables have been made depending on the range of values of the A parameter. The tables contain the $\Psi_0$.

$A = \frac{T^2 \cdot g}{H}$ [Dimensionless]    $\Psi_0 = \frac{(H/T)^2}{g \cdot (s-1) \cdot d}$ [m$^2$]

Where:

T= wave period
g= gravity
H= wave height
s= specific gravity of sediment

d= sediment diameter

| H(m) | T(s) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| **0.05** | 0.7722 | | | | |
| **0.06** | | | | | |
| **0.07** | | | | | |
| **0.08** | | | | | |
| **0.09** | | | | | |
| **0.1** | | | | | |
| **0.11** | | | | | |
| **0.12** | | | | | |
| **0.13** | | | | | |
| **0.14** | | | | | |
| **0.15** | | | | | |
| **0.16** | | | | | |

*Table 6.1: Values of $\Psi_0$ [$m^2$] for A between [180 – 220]*

| H(m) | T(s) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| **0.05** | | 0.1931 | | | |
| **0.06** | | 0.278 | | | |
| **0.07** | | | | | |
| **0.08** | | | | | |
| **0.09** | | | 0.278 | | |
| **0.1** | | | 0.3432 | | |
| **0.11** | | | 0.4153 | | |
| **0.12** | | | 0.4942 | | |
| **0.13** | | | 0.58 | | |
| **0.14** | | | 0.6727 | | |
| **0.15** | | | | | |
| **0.16** | | | | 0.4942 | |

*Table 6.2: Values of $\Psi_0$ [$m^2$] for A between [600 – 1000]*

| H(m) | T(s) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| **0.05** | | | 0.0858 | | |
| **0.06** | | | 0.1236 | | |
| **0.07** | | | | 0.0946 | |
| **0.08** | | | | 0.1236 | |
| **0.09** | | | | 0.1564 | |
| **0.1** | | | | 0.1931 | |
| **0.11** | | | | 0.2336 | 0.1495 |
| **0.12** | | | | | 0.1779 |
| **0.13** | | | | | 0.2088 |
| **0.14** | | | | | 0.2422 |
| **0.15** | | | | | 0.278 |
| **0.16** | | | | | 0.3163 |

*Table 6.3: Values of $\Psi_0$ [$m^2$] for A between [1400 – 2300]*

As it can be observed in the above tables, none of the $\Psi_0$ values were found to overlap because A parameter and $\Psi_0$ are dependent and both also depend on H and T. Therefore the 3 tables can be joined in 1. At the same time, in this final table it is checked if all the waves found above satisfy a wave maximum steepness value defined as: k*h ≈ 1 where:

$k = \frac{2 * \pi}{L}$, wave number.

$w = \frac{2 * \pi}{T}$, wave angular frequency.

Where:

L= wave length [m]

This table (*table 4*) includes which is the H and T values which the study will start with.

| T(s) | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H(m) | w | L | k*h | w | L | k*h | w | L | k*h | w | L | k*h | w | L | k*h |
| 0.05 | 6.283 | 0.679 | 0.462 | 3.141 | 1.382 | 0.227 | 2.094 | 2.103 | 0.149 | - | - | - | - | - | - |
| 0.06 | - | - | - | 3.141 | 1.526 | 0.247 | 2.094 | 2.280 | 0.165 | - | - | - | - | - | - |
| 0.07 | - | - | - | - | - | - | - | - | - | 1.570 | 3.288 | 0.133 | - | - | - |
| 0.08 | - | - | - | - | - | - | - | - | - | 1.570 | 3.549 | 0.141 | - | - | - |
| 0.09 | - | - | - | - | - | - | 2.0944 | 2.8137 | 0.201 | 1.570 | 3.725 | 0.151 | - | - | - |
| 0.1 | - | - | - | - | - | - | 2.094 | 2.935 | 0.214 | 1.570 | 3.964 | 0.158 | - | - | - |
| 0.11 | - | - | - | - | - | - | 2.094 | 3.105 | 0.222 | 1.570 | 4.115 | 0.167 | 1.256 | 5.153 | 0.134 |
| 0.12 | - | - | - | - | - | - | 2.0944 | 3.2104 | 0.2349 | - | - | - | 1.256 | 5.380 | 0.140 |
| 0.13 | - | - | - | - | - | - | 2.094 | 3.338 | 0.244 | - | - | - | 1.256 | 5.598 | 0.145 |
| 0.14 | - | - | - | - | - | - | 2.094 | 3.462 | 0.254 | - | - | - | 1.256 | 5.808 | 0.151 |
| 0.15 | - | - | - | - | - | - | - | - | - | - | - | - | 1.256 | 6.011 | 0.156 |
| 0.16 | - | - | - | - | - | - | - | - | - | 1.570 | 4.953 | 0.202 | 1.256 | 6.206 | 0.162 |

*Table 6.4: Calculation of the steepness of the waves (k*h)*

## *6.2 Sensitivity Test*

As the lowest mobility number in the table 6.4 was supposed to cause suction, when comparing with Nielsen's [2004] results, a test has been done to check, with the conditions of the first case, which is the minimum wave height with a wave period of 1 second that can produce suction of the bed sediment. This height was 4cm.

Because there was suction with really small wave heights, in this case zero, the conclusion was that doing tests with the kind of sand used as sediment was unnecessary because there is always suction with this sand. This is because no critical suction situations could be found.

## *6.3 Results. Design diagrams from Cases 1 – 10*

The critical suction happens when the sediment is exposed to the main flow and is transported away. For lower mobility numbers movements of the sediment can take place in the holes and between the stones.

The critical mobility can be seen in the following figures 6.2 to 6.5. The results make good sense. For decreasing d/D, the critical mobility number increases. That corresponds to what was expected. The smaller the d/D, the better the sediment would be protected. This is because the longer distance the descending eddy has to do between the holes of the protection (one or two layers of stones), the longer distance the sediment needs to be lifted out of the holes of the protection. This gives that the sediment must be more mobile if it has to be removed (suction).

For the small values of d/D the distance between the curves seems to decrease. This indicates that there may be a vertical or inclined asymptote for all the curves, but to be certain, data with even smaller d/D must be obtained.

In the figures where the comparison of the results for the two slopes is plotted, it makes sense that for the same sediment and wave conditions, a higher mobility number is required for the smoother slope 1:30 than for the steeper slope 1:13.

The first design diagrams are the ones elaborated from the offshore measurements and the second from the local measurements.

In each of these two groups the following elements are plotted:

- All the results for one and two layers for all the cases studied.
- Design diagram with the results for only one layer of armour protection
- Design diagram with the results for only two layers of armour protection
- Design diagrams comparing one and two layers of armour protection for a similar range of the parameter A values.
- Design diagrams comparing the slope 1:13 and 1:30 with one layer of armour protection.

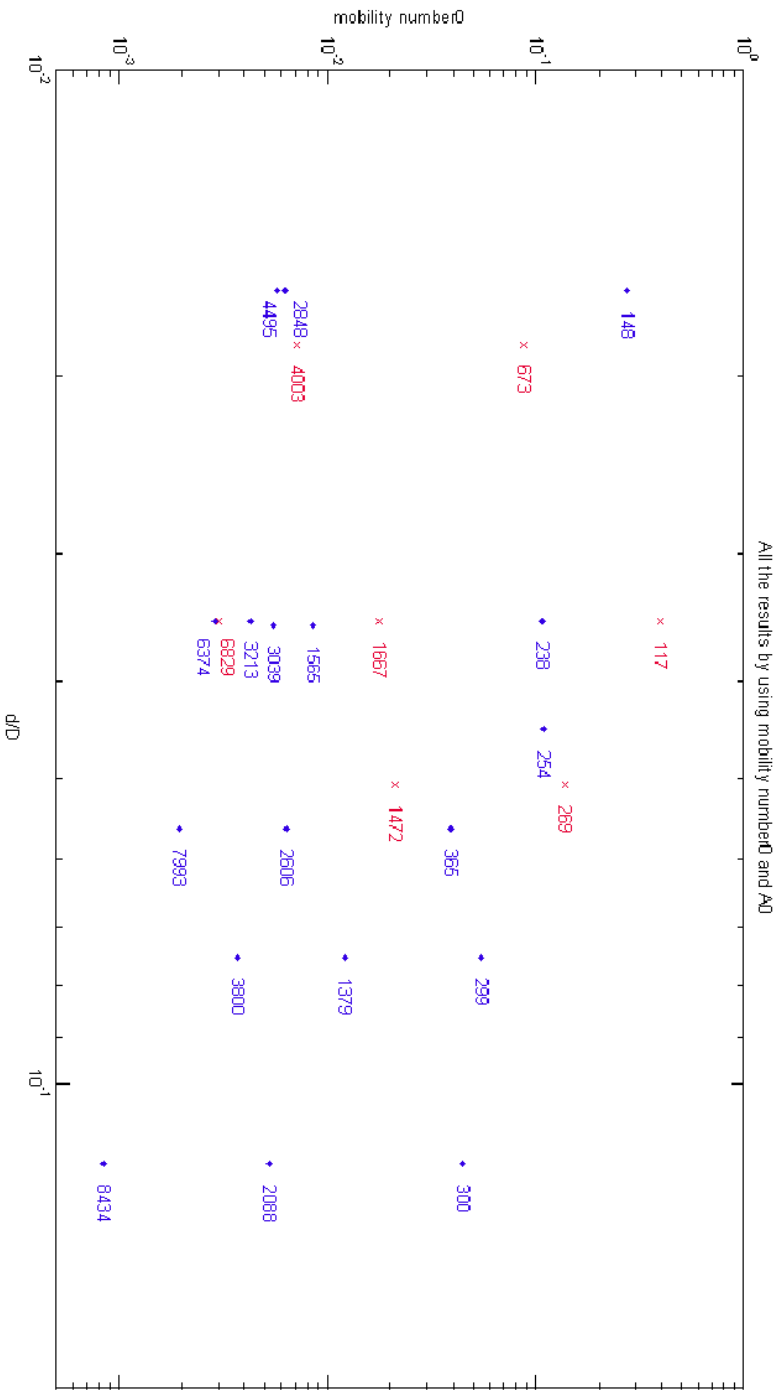



*Figure 6.1: All the results by using ψ0 and A0. Slope 1:13 Blue dots: one layer. Red crosses: two layers.*

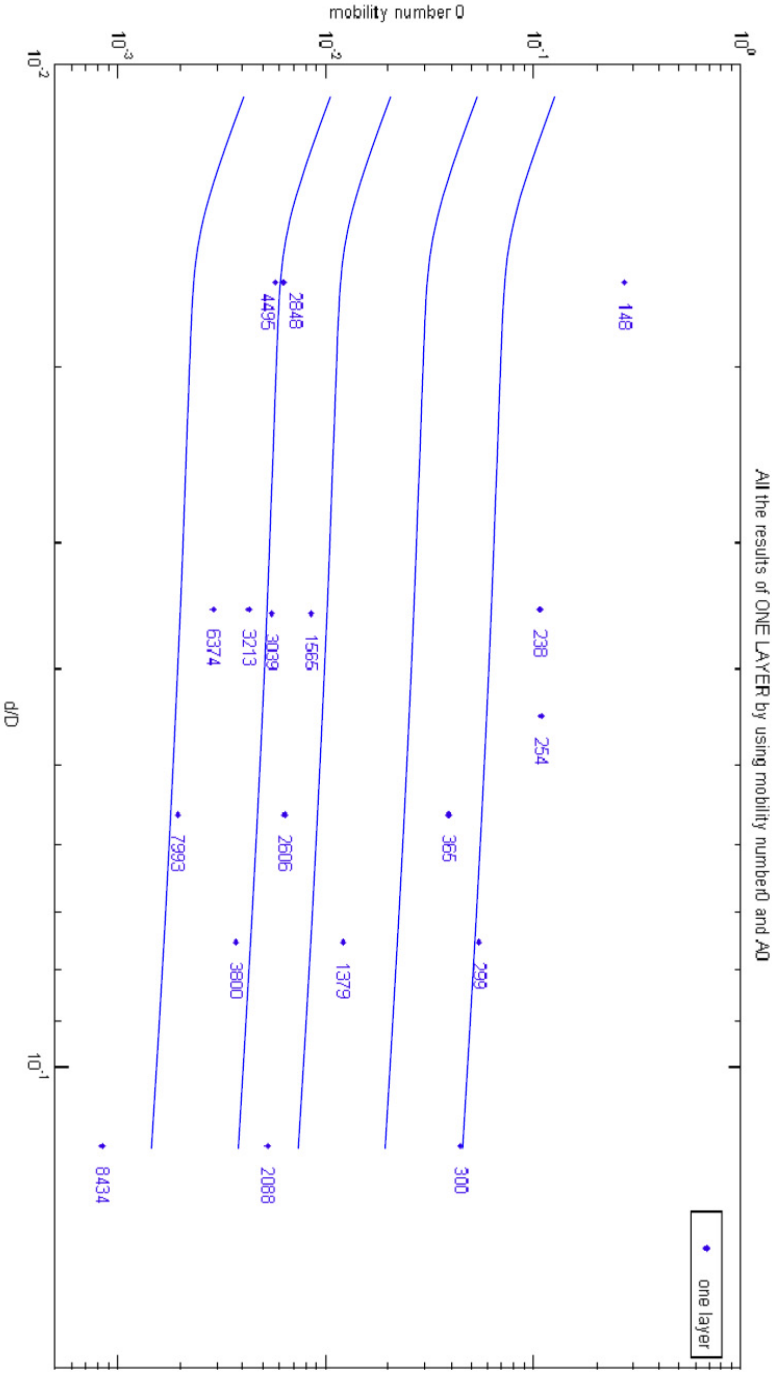



*Figure 6.2: All the results of one layer of scour protection by using ψ0 and A0. Slope 1:13*

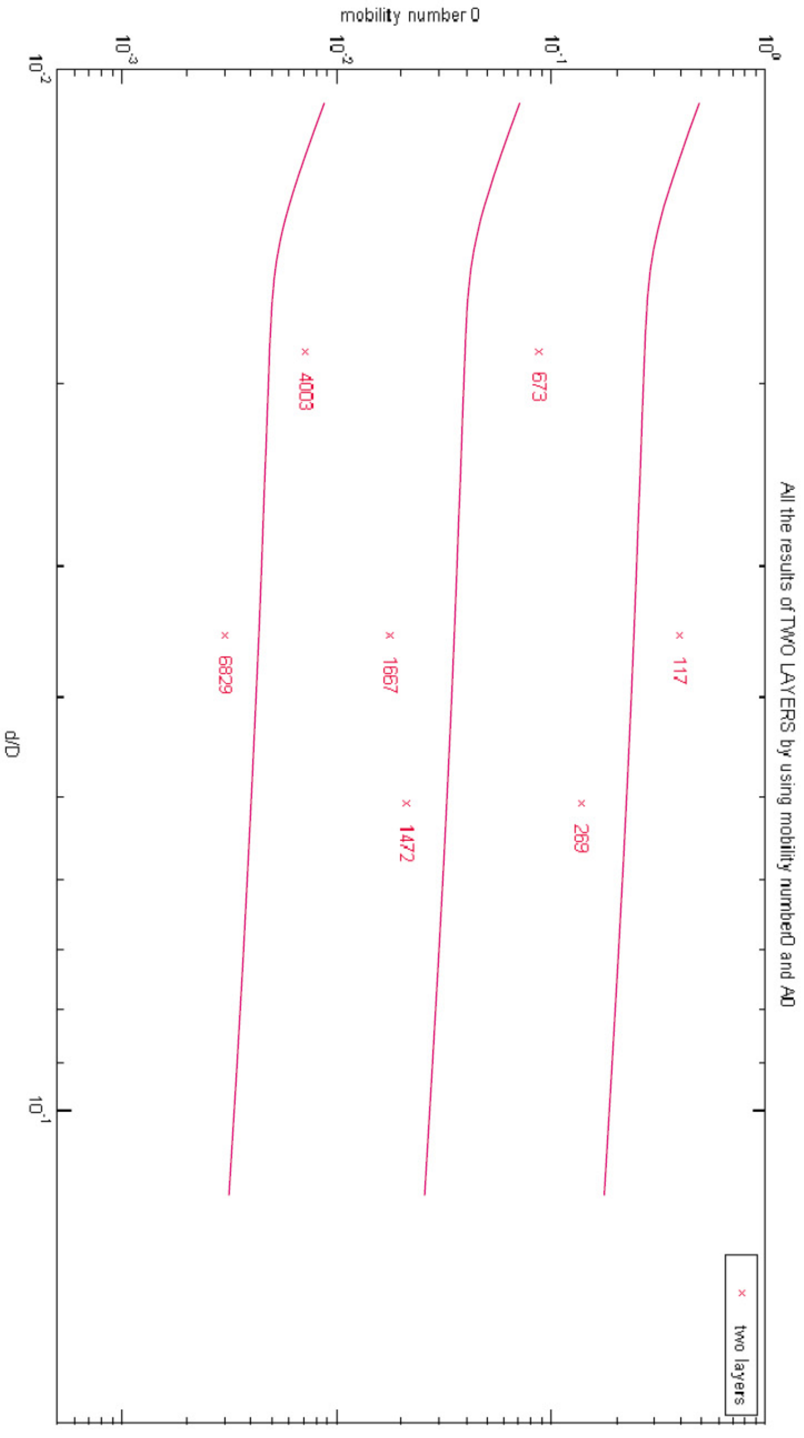



*Figure 6.3: All the results of two layers of scour protection by using ψ0 and A0. Slope 1:13*

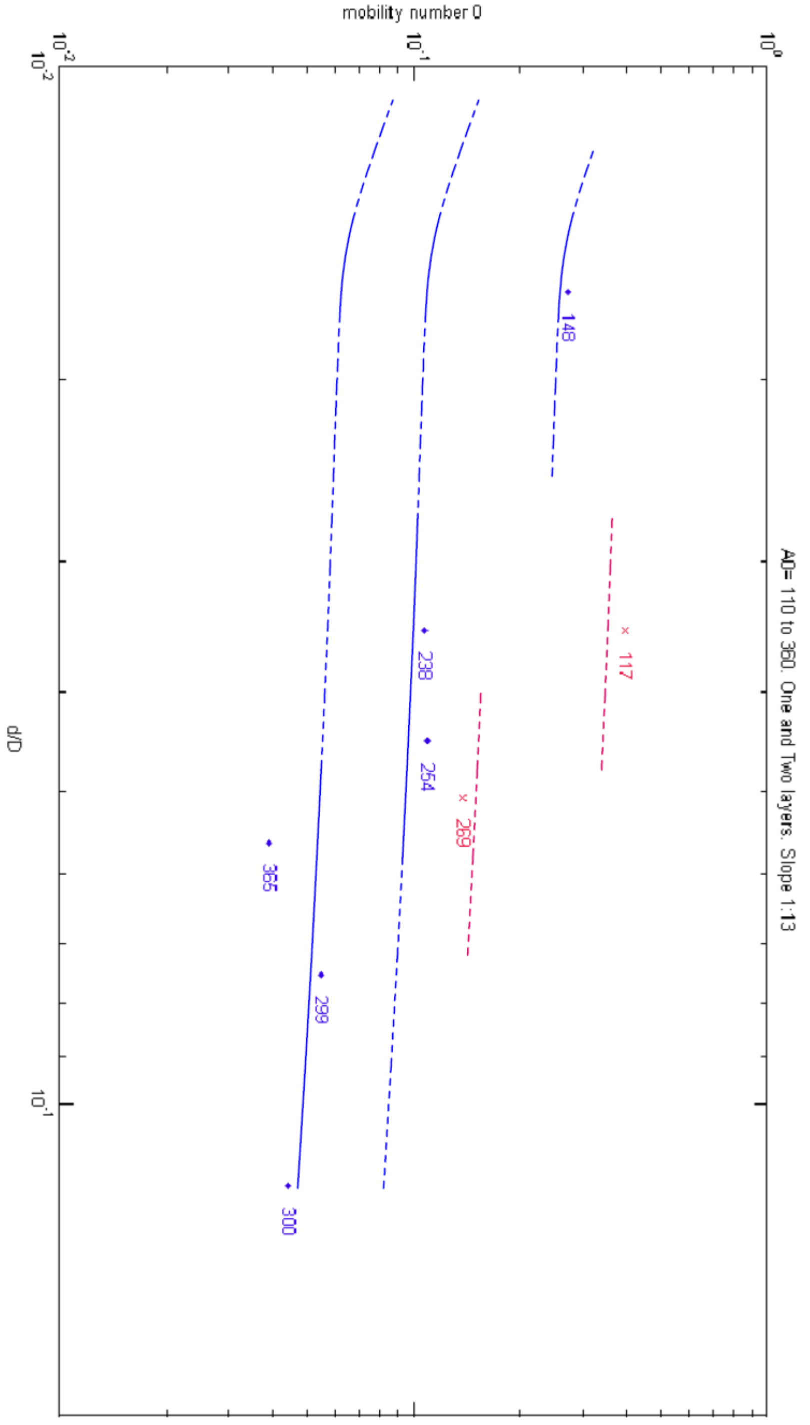



*Figure 6.4: Comparison of the results of one and two layers of scour protection by using ψ0 and A0=110 to 350. Slope 1:13. Blue dots: 1 layer. Red crosses: 2 layers*

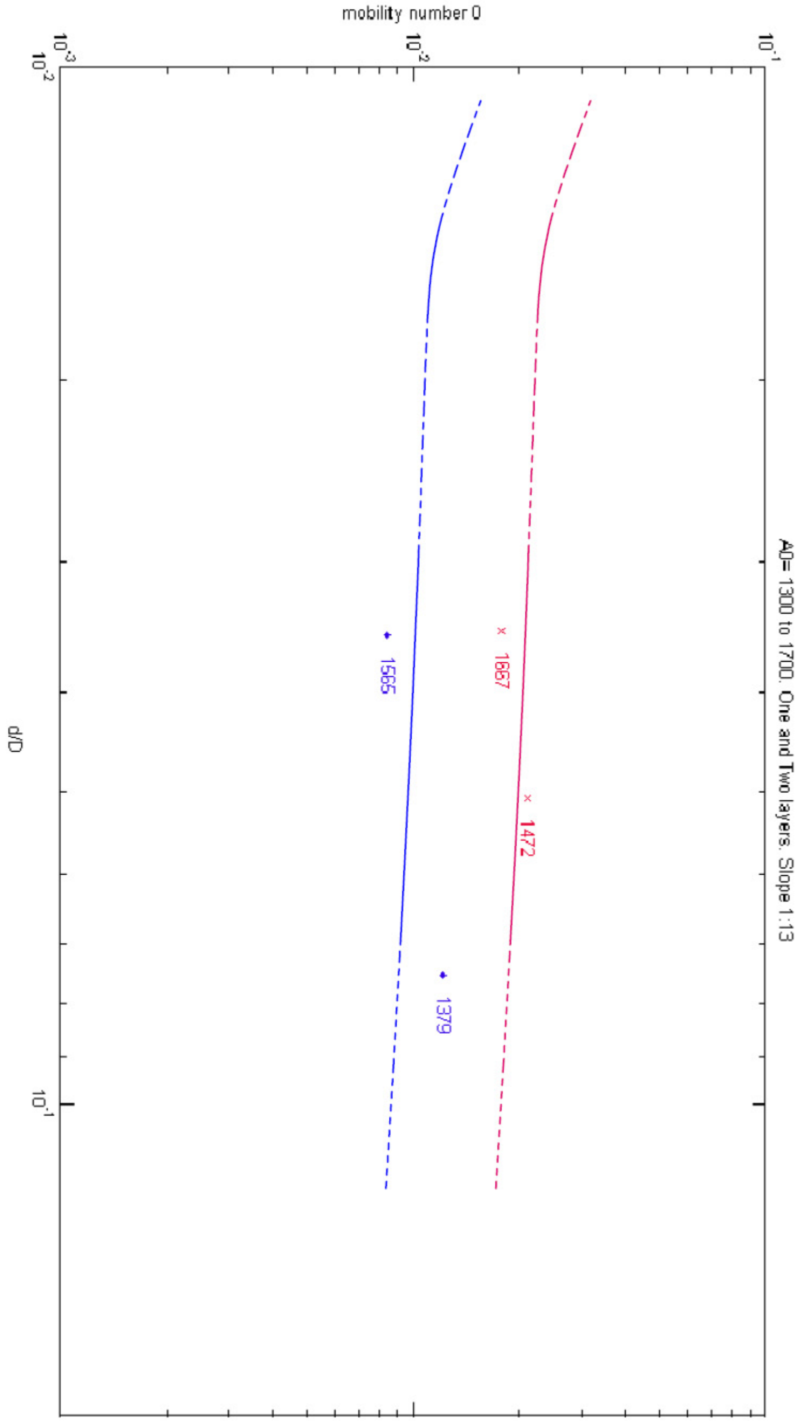



*Figure 6.5: Comparison of the results of one and two layers of scour protection by using ψ0 and A0=1300 to 1700. Slope 1:13. Blue dots: 1 layer. Red crosses: 2 layers*

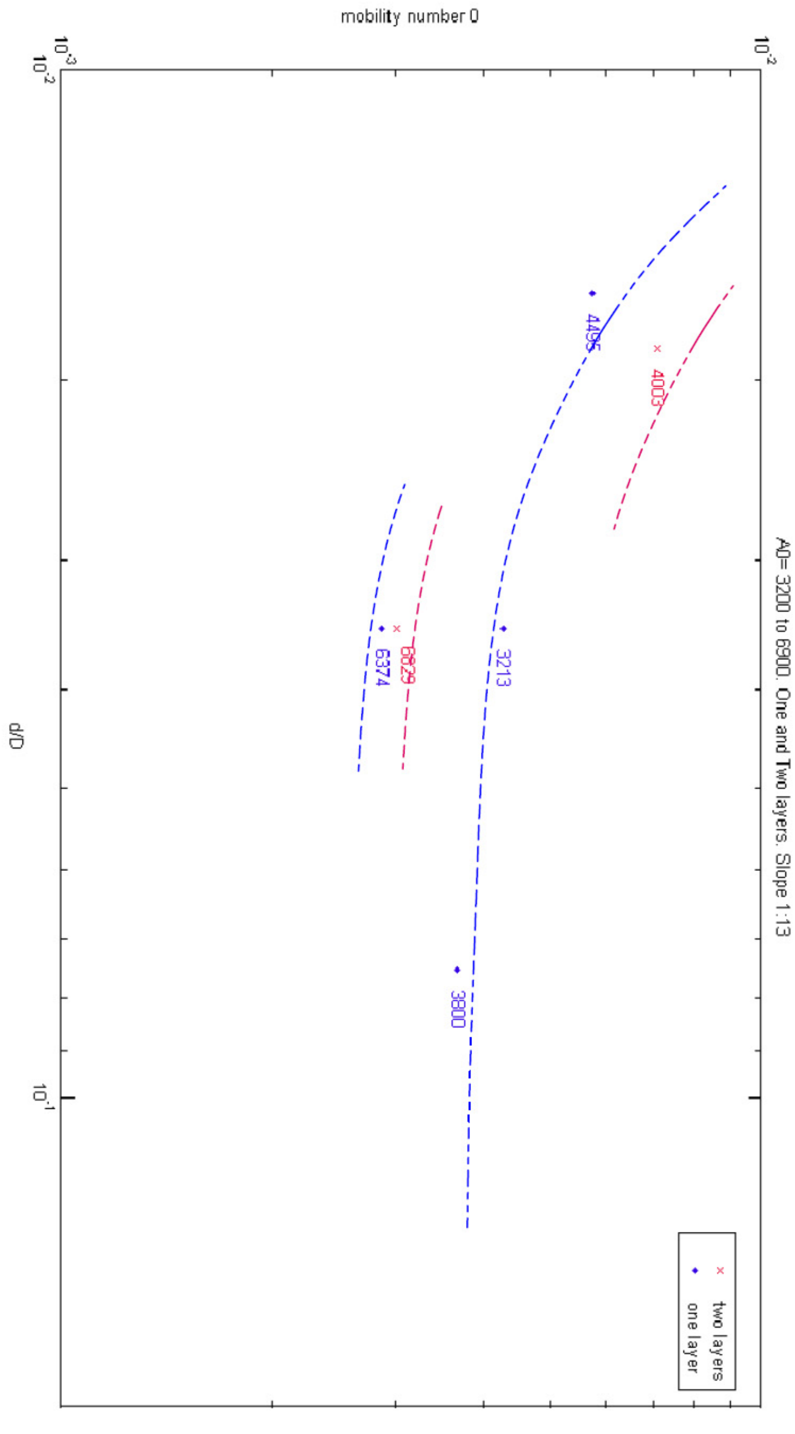



*Figure 6.6: Comparison of the results of one and two layers of scour protection by using $\psi_0$ and $A_0$=1300 to 1700. Slope 1:13. Blue dots: 1 layer. Red crosses: 2 layers*

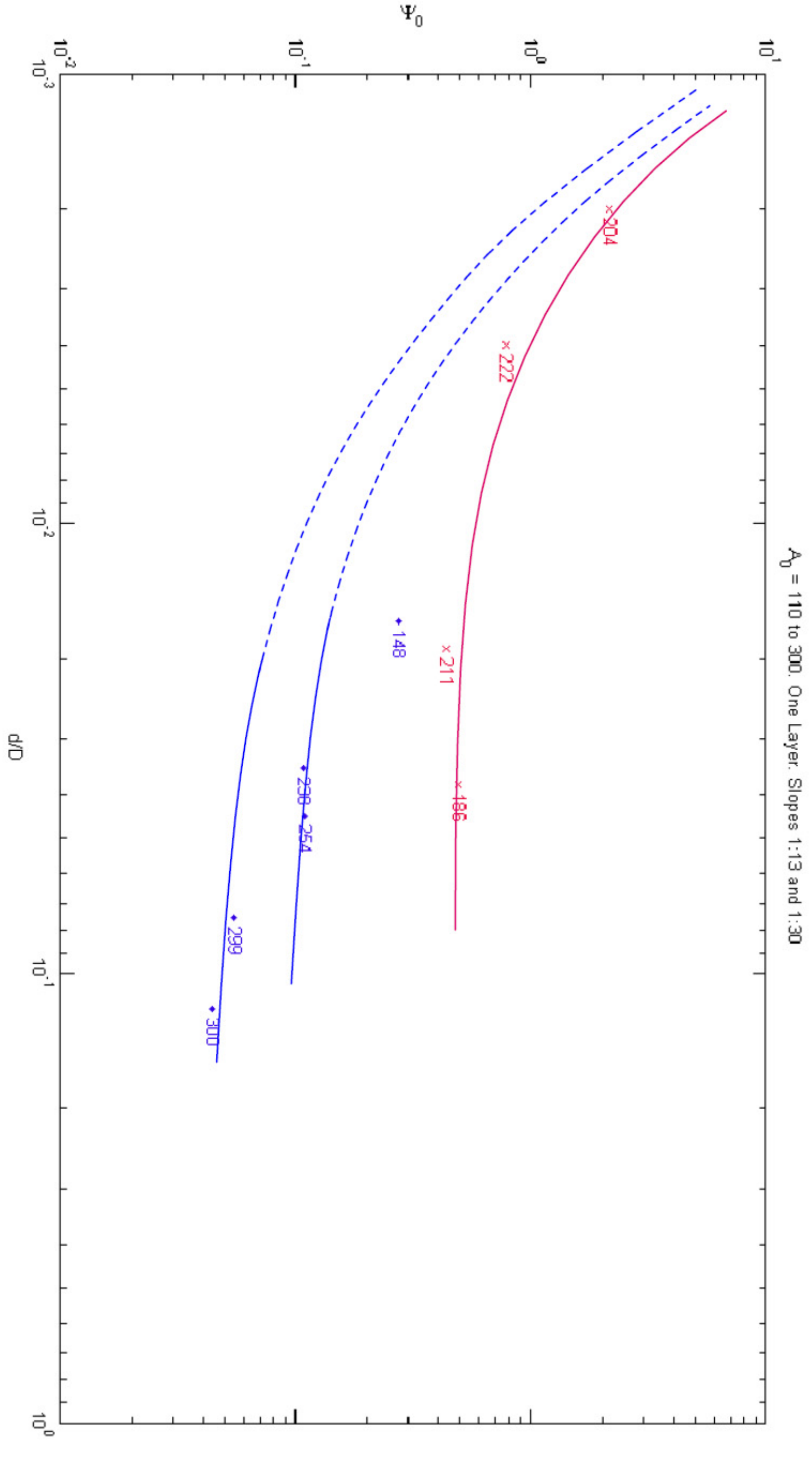



*Figure 6.7: Comparison of the results for two slopes with one layer of scour protection by using $\psi_0$ and $A_0$ = 110 to 300. Blue dots: slope 1:13. Red crosses: slope 1:30*

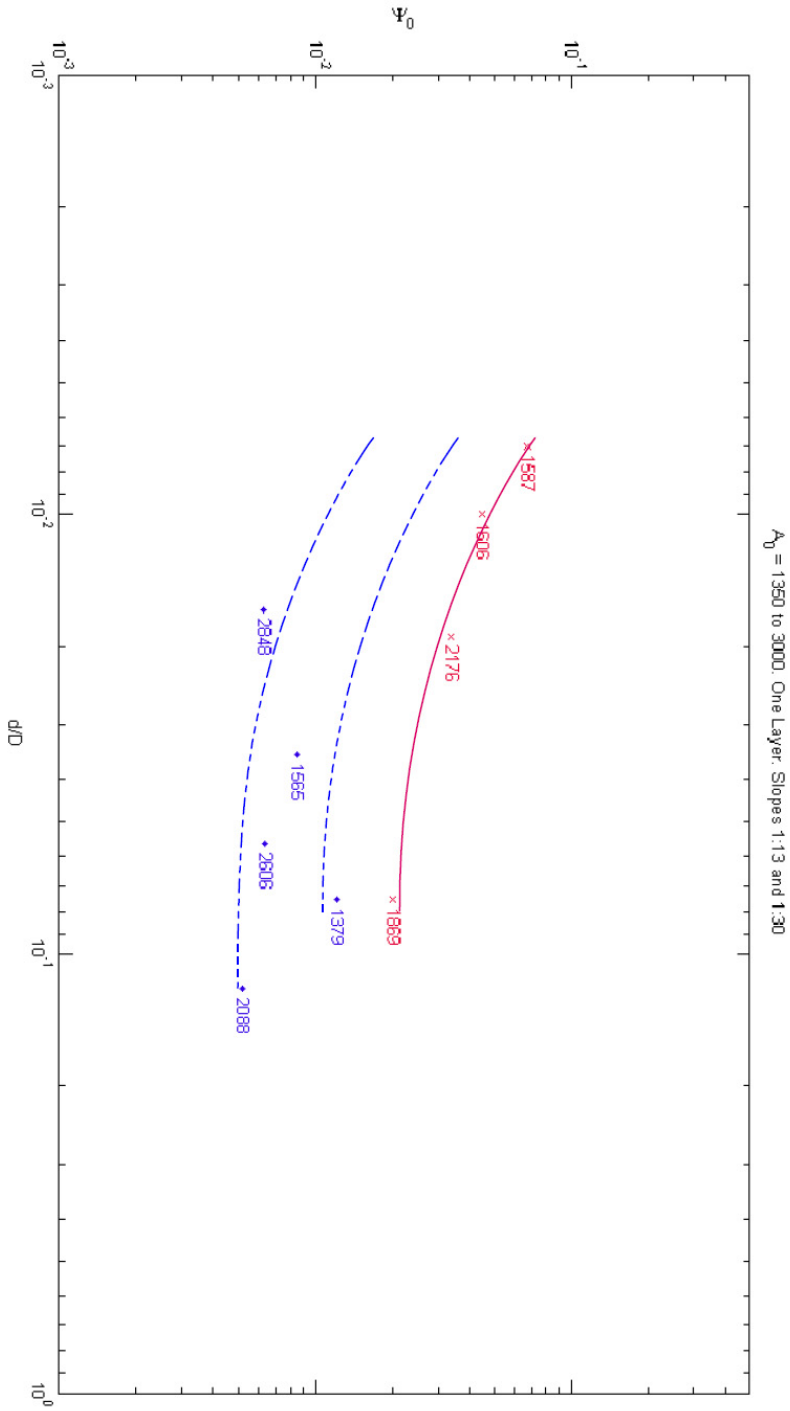



*Figure 6.8: Comparison of the results for two slopes with one layer of scour protection by using $\psi_0$ and $A_0$ = 1350 to 3000. Blue dots: slope 1:13. Red crosses: slope 1:30*

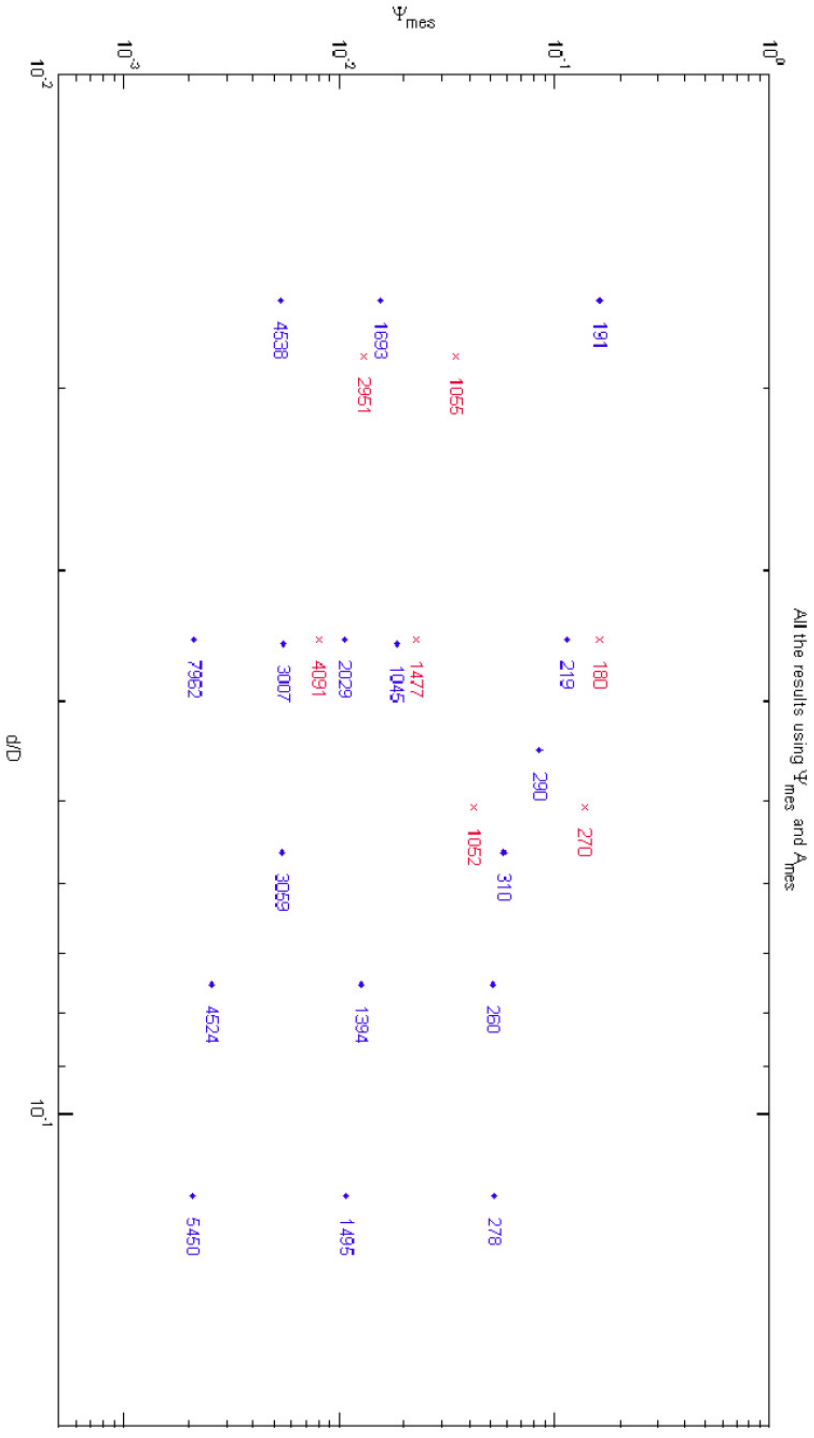



*Figure 6.9: All the results by using $\psi_{mes}$ and $A_{mes}$. Slope 1:13 Blue dots: one layer. Red crosses: two layers.*

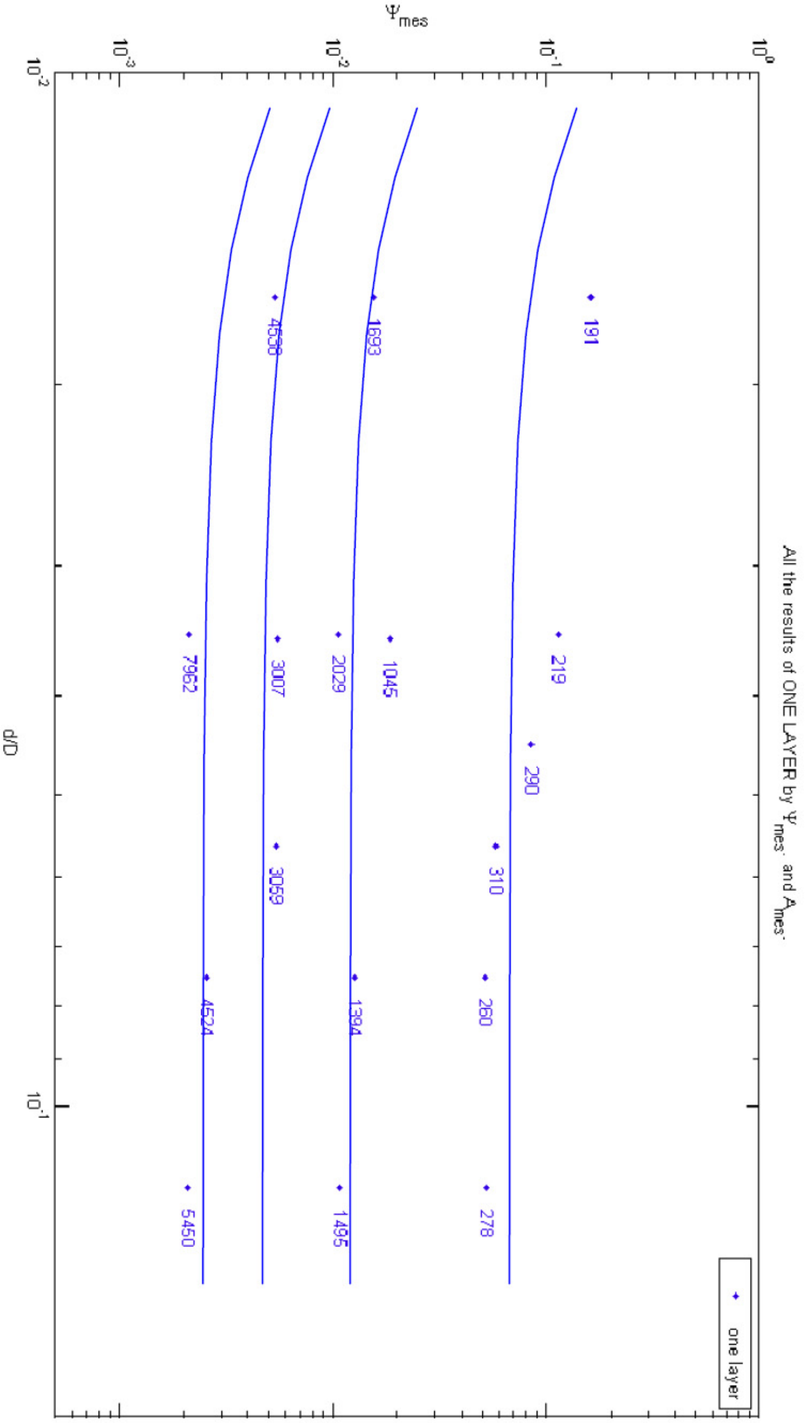



*Figure 6.10: All the results of one layer of scour protection by using $\psi_{mes}$ and $A_{mes}$. Slope 1:13*

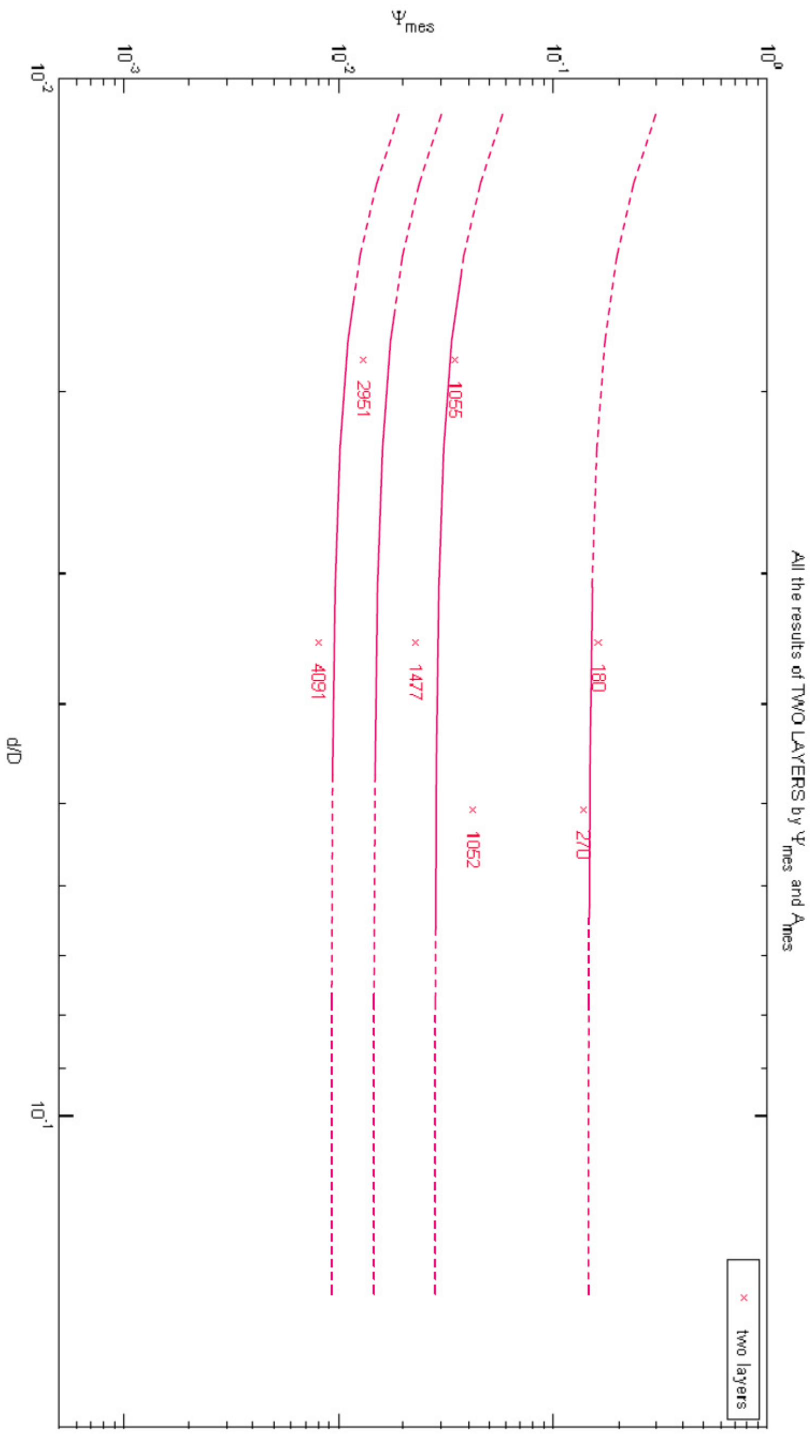



*Figure 6.11: All the results of two layers of scour protection by using $\psi_{mes}$ and $A_{mes}$. Slope 1:13*

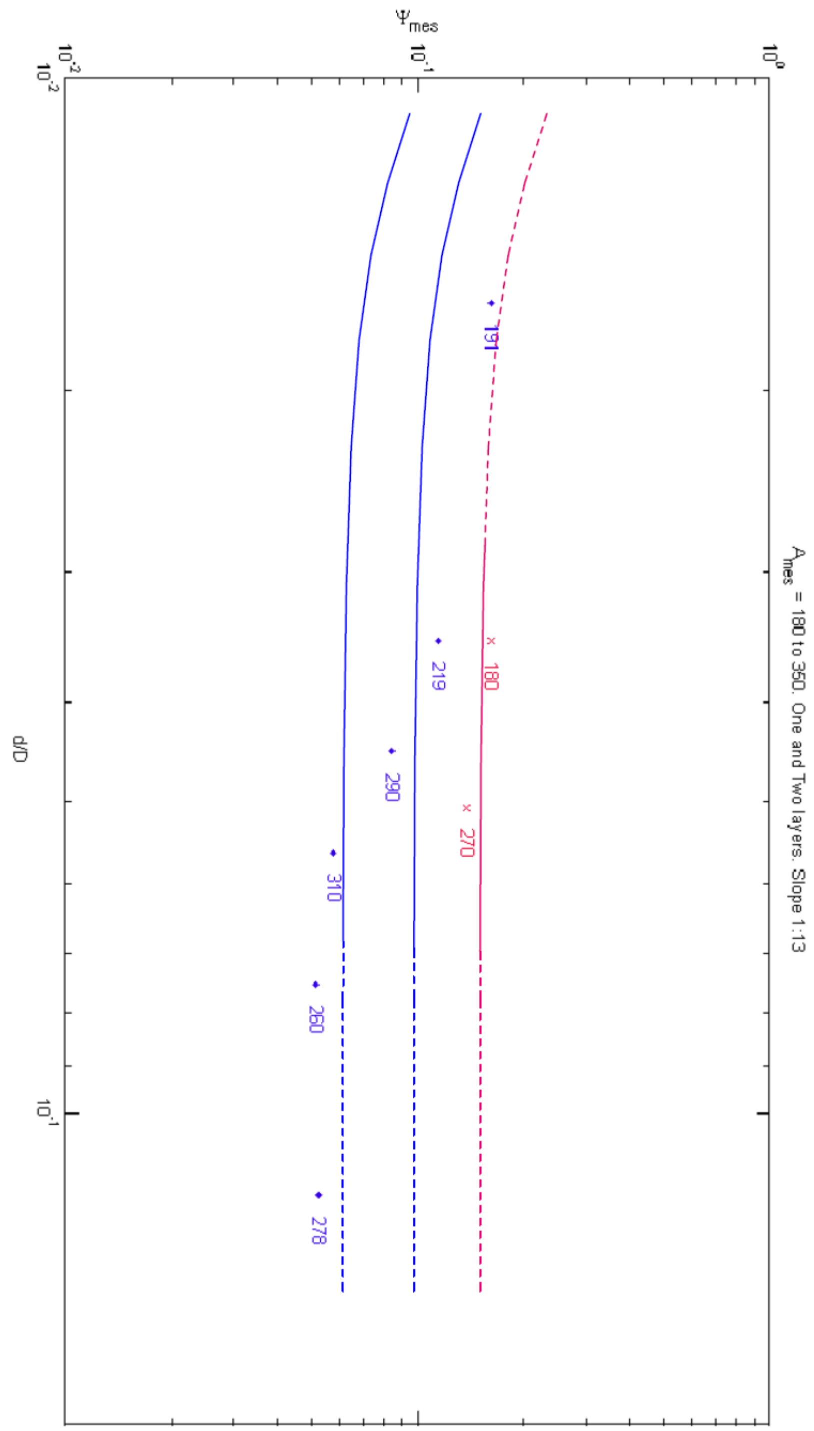



*Figure 6.11: Comparison of the results of one and two layers of scour protection by using $\psi_{mes}$ and $A_{mes}$=180 to 350. Slope 1:13. Blue dots: 1 layer. Red crosses: 2 layers*

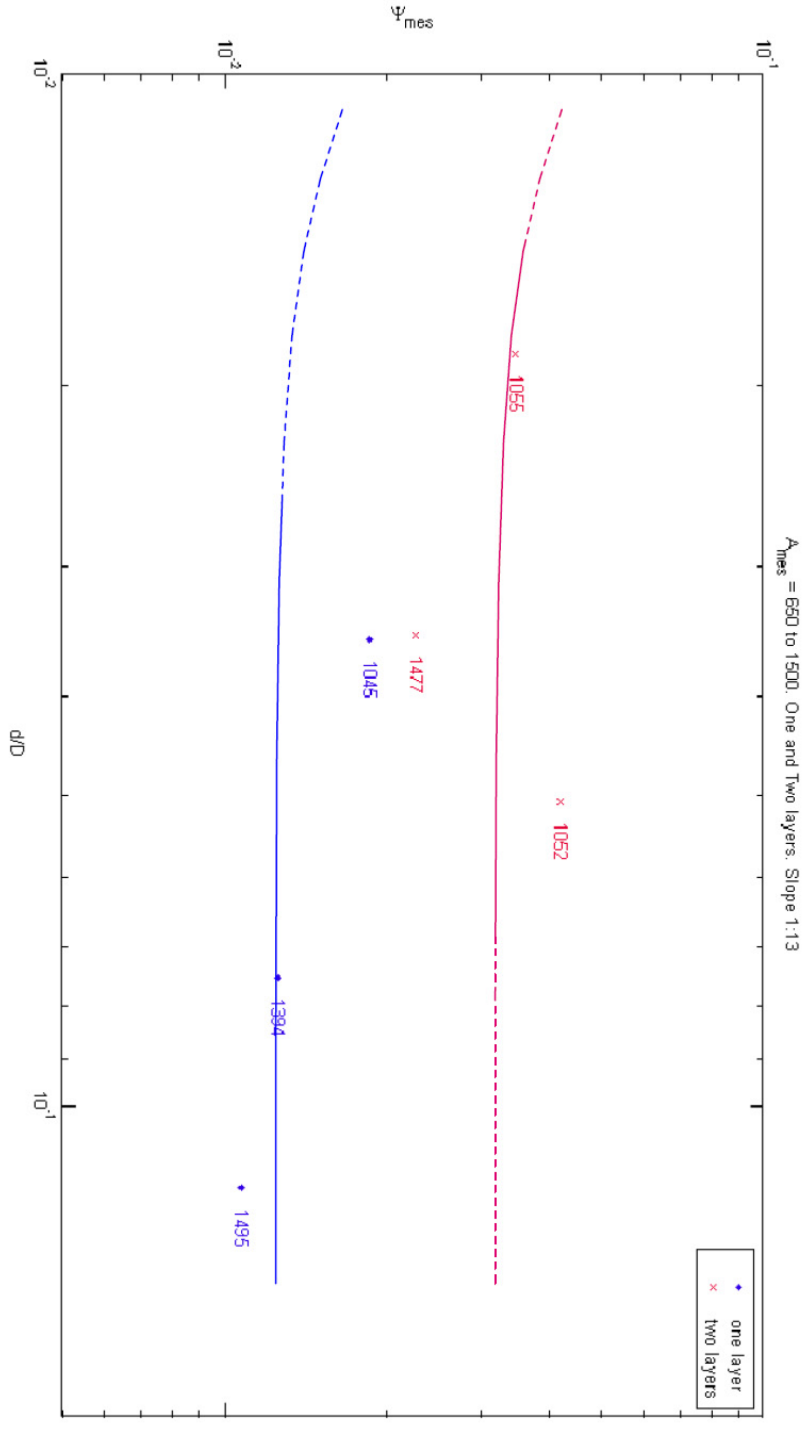



*Figure 6.12: Comparison of the results of one and two layers of scour protection by using $\psi_{mes}$ and $A_{mes}$=650 to 1500. Slope 1:13. Blue dots: 1 layer. Red crosses: 2 layers*

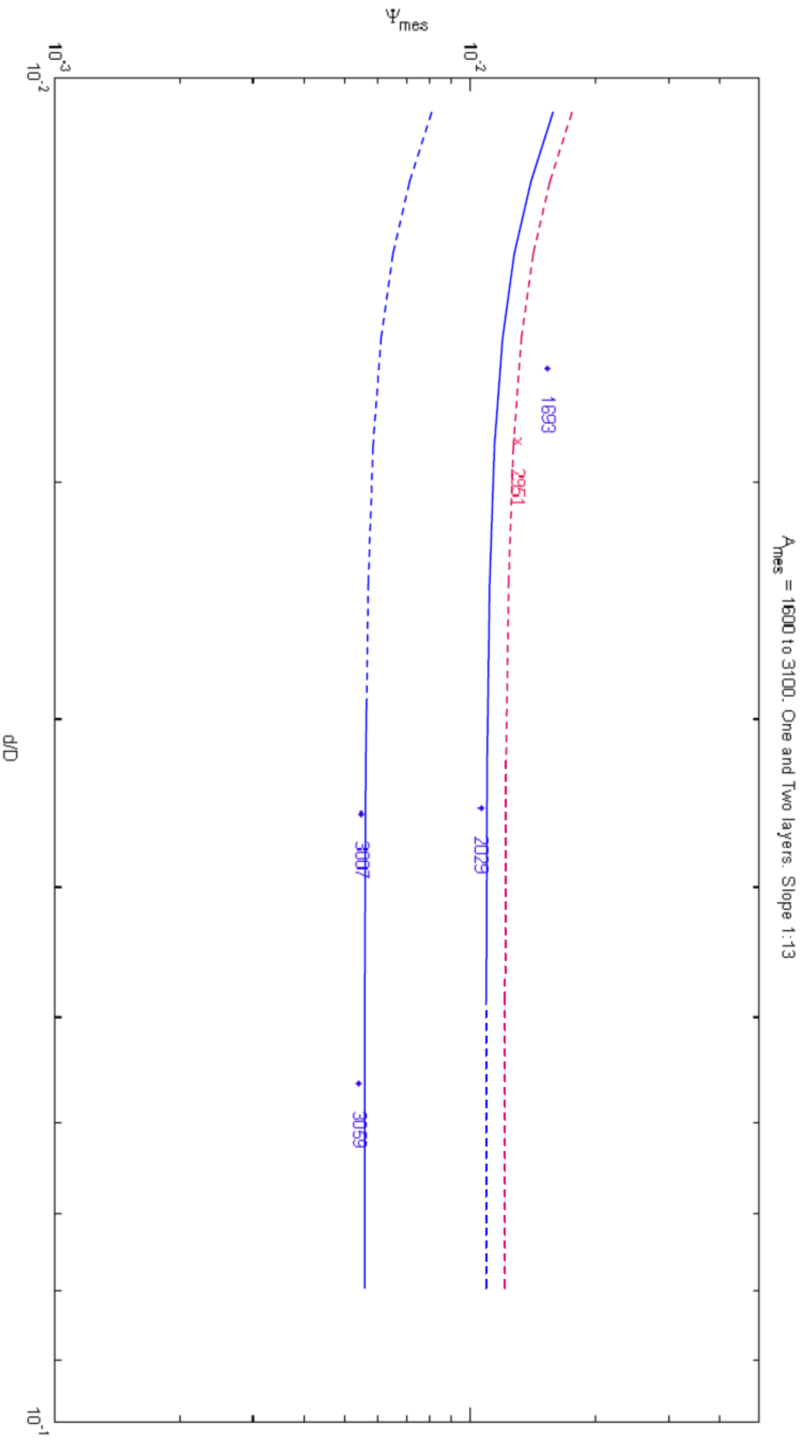



*Figure 6.13: Comparison of the results of one and two layers of scour protection by using $\psi_{mes}$ and $A_{mes}$=1600 to 3100. Slope 1:13. Blue dots: 1 layer. Red crosses: 2 layers*

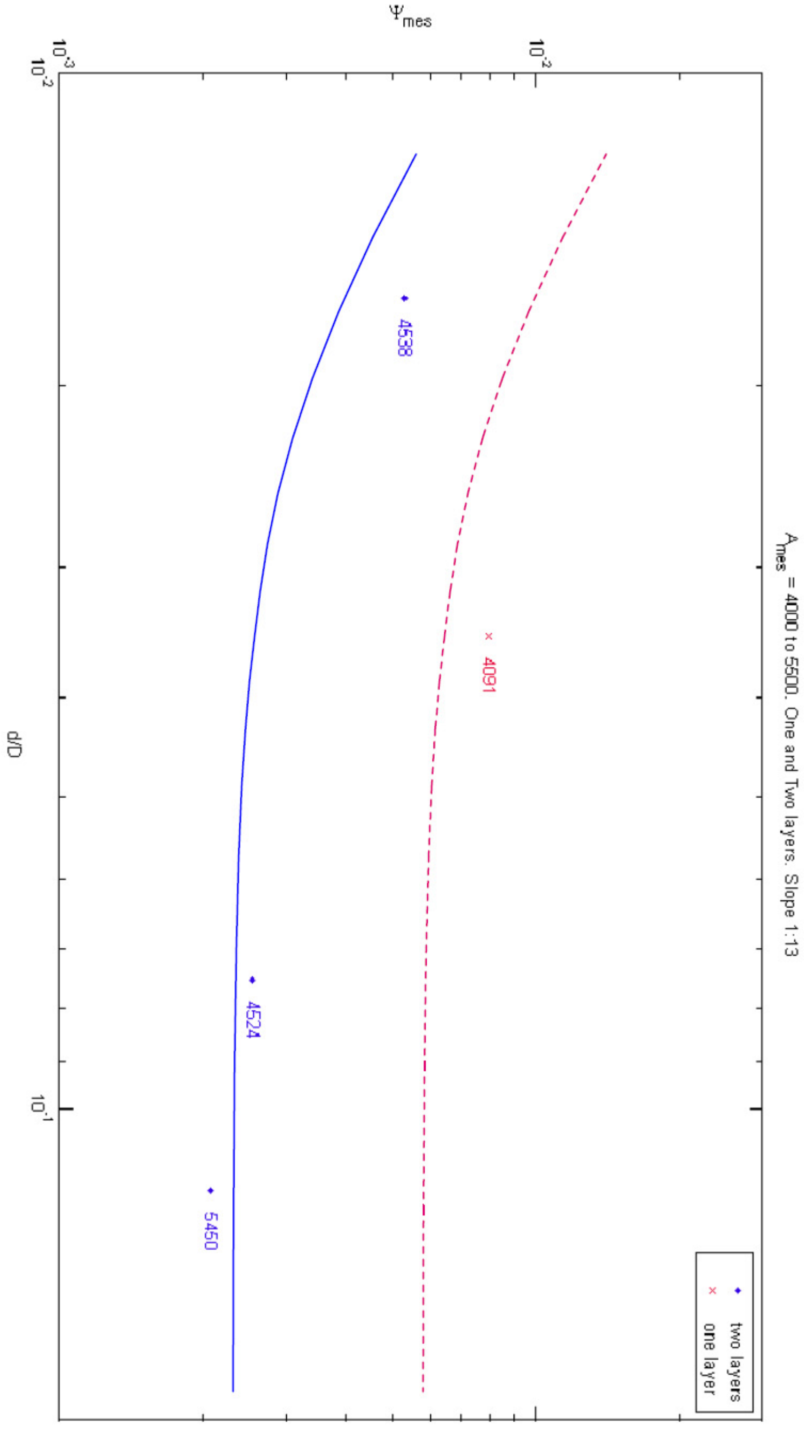



*Figure 6.14: Comparison of the results of one and two layers of scour protection by using $\psi_{mes}$ and $A_{mes}$=4000 to 5500. Slope 1:13. Blue dots: 1 layer. Red crosses: 2 layers*

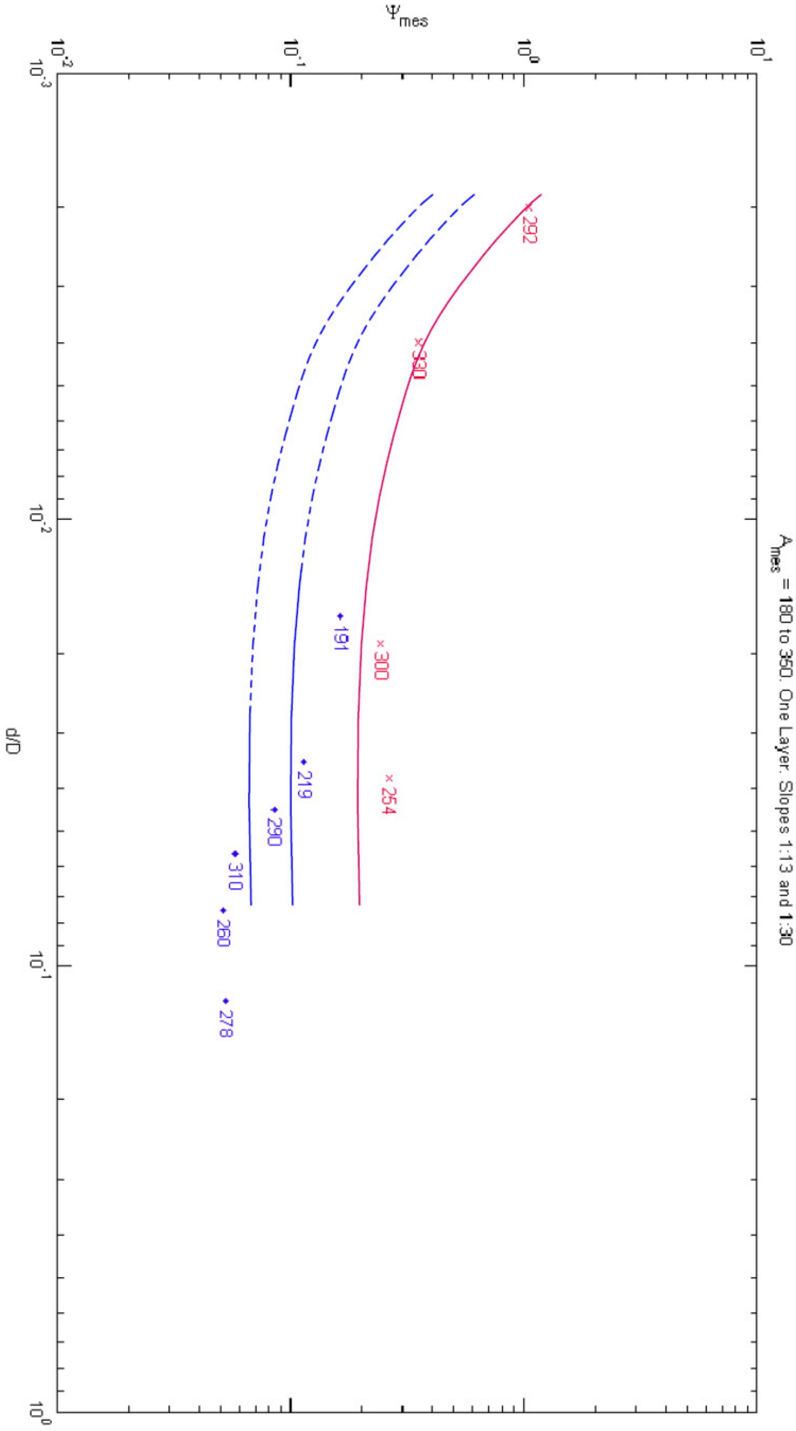



*Figure 6.15: Comparison of the results for two slopes with one layer of scour protection by using $\psi_{mes}$ and $A_{mes}$ = 180 to 350. Blue dots: slope 1:13. Red crosses: slope 1:30*

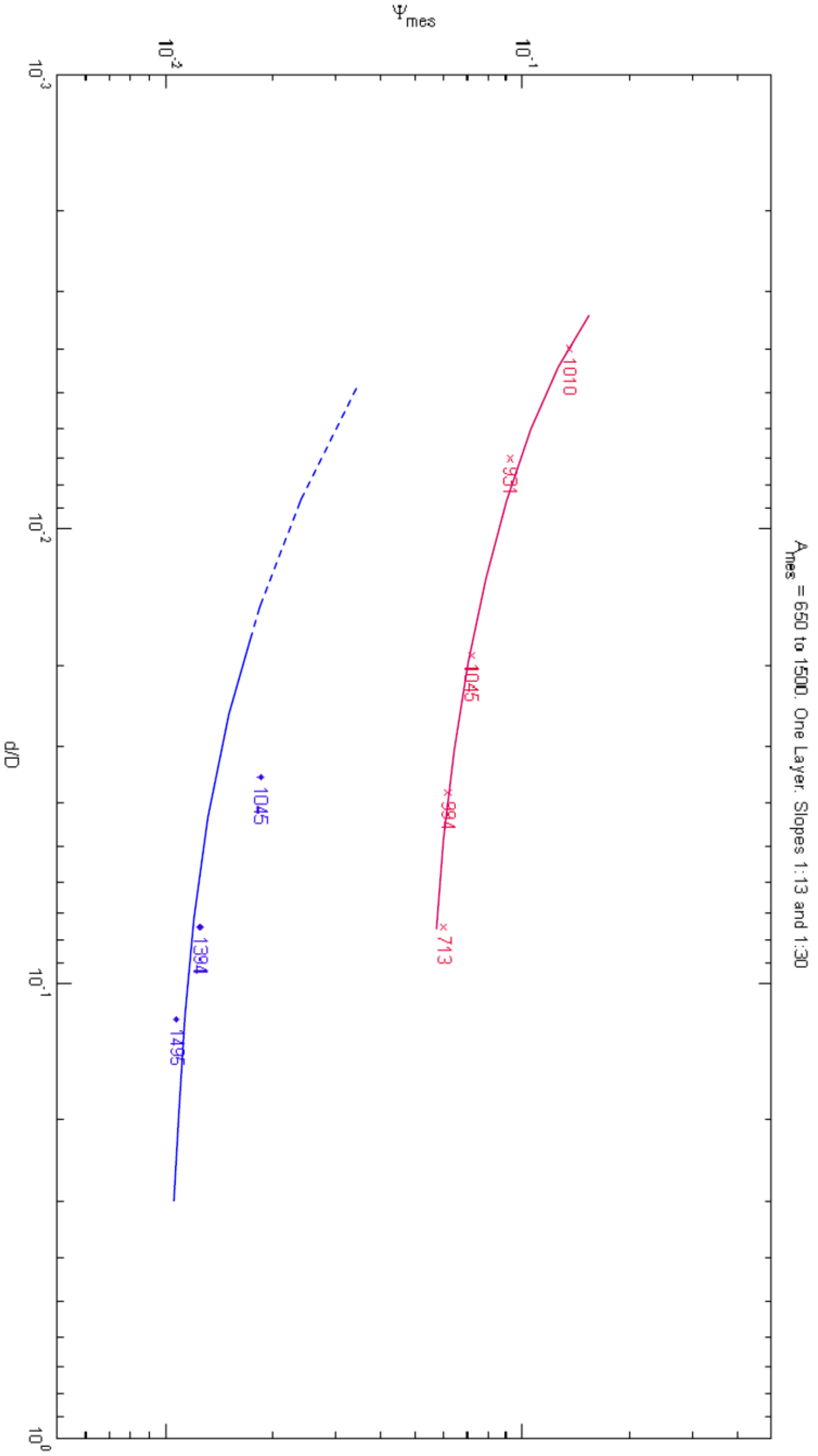



*Figure 6.16: Comparison of the results for two slopes with one layer of scour protection by using $\psi_{mes}$ and $A_{mes}$ = 650 to 1500. Blue dots: slope 1:13. Red crosses: slope 1:30*

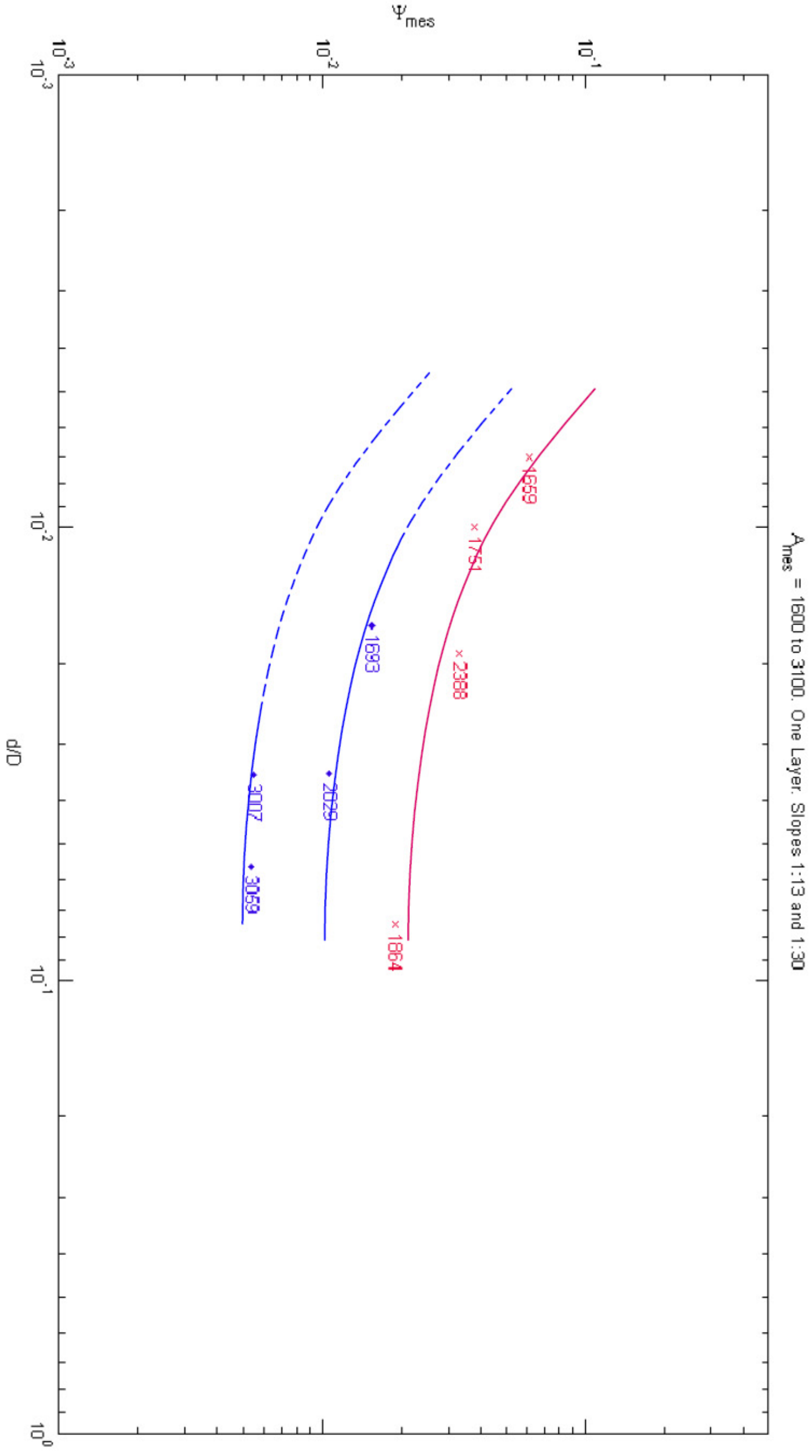



*Figure 6.17: Comparison of the results for two slopes with one layer of scour protection by using $\psi_{mes}$ and $A_{mes}$ = 1600 to 3100. Blue dots: slope 1:13. Red crosses: slope 1:30*

### *6.4 Has one layer of protection the same effect as two layers of protection with half size stones?*

To answer this question, three comparisons have been carried out depending on the size of the stone layer and the sediment, so the d/D is equal or very similar.

In each comparison,the mobility number $\psi_0$ vs. d/D is plotted for each test, to have a visualization of which test has a higher mobility number with similar A parameter values.

| TEST INFORMATION | STONES | | SEDIMENT | | | | FLOW PROPERTIES | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Test Number | D [cm] | Number of layers | $d_{50}$ [cm] | $s=\rho_s/\rho$ | Single/ Sediment | d/D | $h_0$ [cm] | $H_0$ [cm] | T [s] | $\psi_0$ | $A_0$ |
| 7 | 4 | 2 of 2.5 cm | 0.14 | 2.65 | Sediment | 0.035 | 38.1 | 4.5 | 5.5 | 0.0030 | 6829 |
| 8 | 4 | 2 of 2.5 cm | 0.14 | 2.65 | Sediment | 0.035 | 38.6 | 6.8 | 3.4 | 0.0178 | 1667 |
| 9 | 4 | 2 of 2.5 cm | 0.14 | 2.65 | Sediment | 0.035 | 39.3 | 10.3 | 1.1 | 0.3956 | 117 |
| 11 | 7.5 | 2 of 4.0 cm | 0.38 | 1.39 | Single | 0.0507 | 38.0 | 4.7 | 1.2 | 0.1378 | 269 |
| 15 | 4 | 1 | 0.14 | 2.65 | Sediment | 0.035 | 37.3 | 3.9 | 5.0 | 0.0029 | 6374 |
| 16 | 4 | 1 | 0.14 | 2.65 | Sediment | 0.035 | 36.0 | 2.9 | 3.0 | 0.0043 | 3213 |
| 17 | 4 | 1 | 0.14 | 2.65 | Sediment | 0.035 | 36.5 | 5.3 | 1.1 | 0.1071 | 238 |
| 18 | 7.5 | 2 of 4.0 cm | 0.14 | 2.65 | Sediment | 0.0187 | 39.4 | 6.5 | 5.1 | 0.0071 | 4003 |
| 20 | 8.5 | 1 | 0.38 | 1.39 | Single | 0.0447 | 39.2 | 3.9 | 1.5 | 0.1094 | 254 |
| 25 | 8.5 | 1 | 0.14 | 2.65 | Sediment | 0.0165 | 38.4 | 5.6 | 4.5 | 0.0057 | 4495 |

*Table 6.5: Data for the comparisons.*

### 6.4.1 First Comparison

Sediment:

- $d_{50}$ = 0.14

Armour protection:

- 2 layers of 1 $D_{50}$ = 2.5 cm. Tests: 7,8, 9
- 1 layer of $D_{50}$ = 4 cm. Tests: 15,16,17

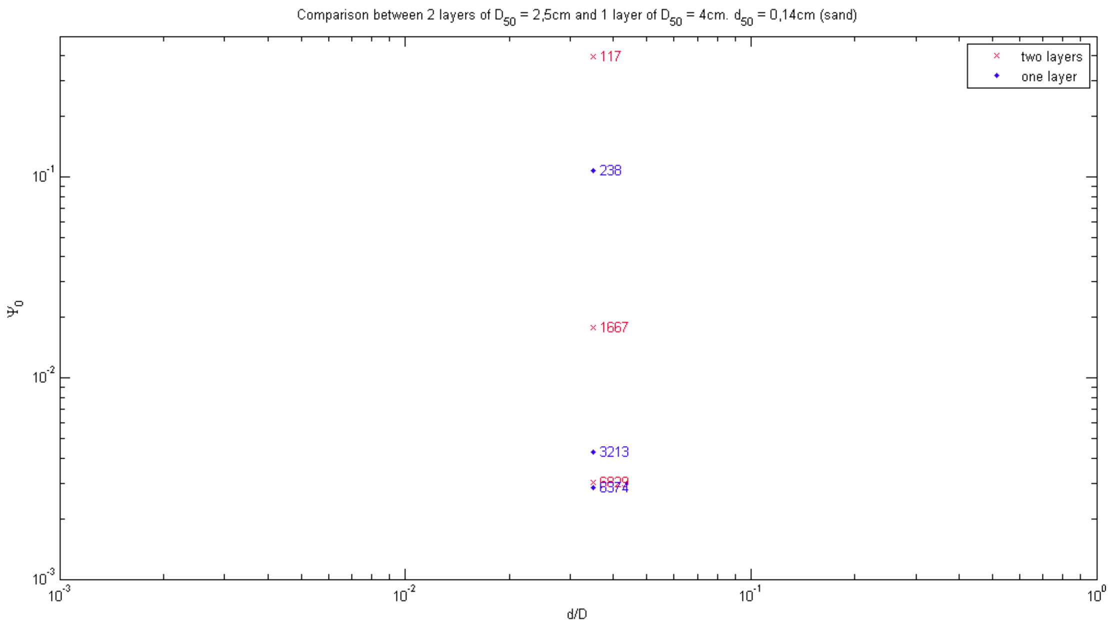



*Figure 6.18: Plot using $\psi_0$ and $A_0$ of the tests 7, 8 and 9 of the case 3 and tests 15, 16 and 17 of the case 6*

It can be seen that the difference of mobility number between the two tests with $A_0$ around 6500 is much smaller than for the tests with $A_0$ = 110-250.

### 6.4.2 Second Comparison

Single particles (plastic):

- $d_{50}$ = 0.38

Armour protection:

- 2 layers of 1 $D_{50}$ = 4 cm. Test: 11
- 1 layer of $D_{50}$ = 8,5 cm. Test: 20

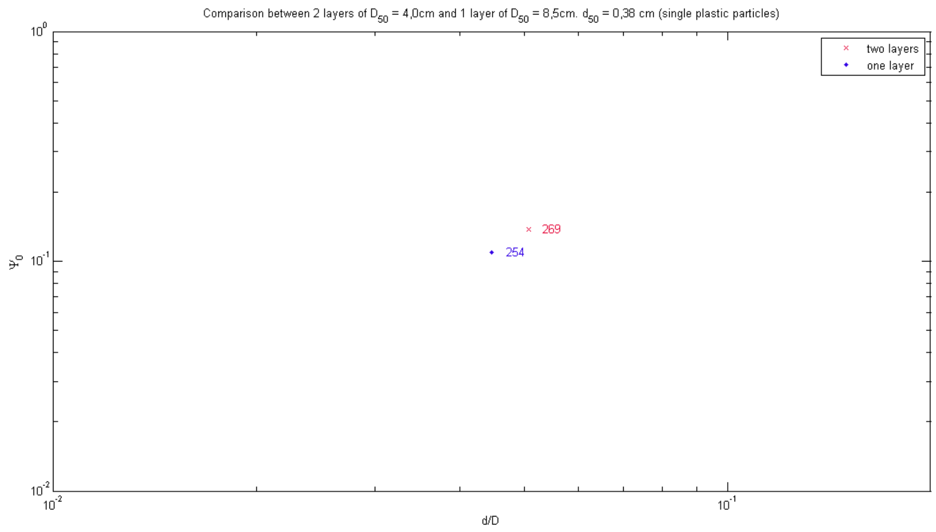



*Figure 6.19: Plot using $\psi_0$ and $A_0$ of test 11 of the case 4 and test 20 of the case 8.*

### 6.4.3 Third Comparison

Sediment:

- $d_{50}$ = 0.14

Armour protection:

- 2 layers of 1 $D_{50}$ = 4 cm. Test: 18
- 1 layer of $D_{50}$ = 8,5 cm. Test: 25

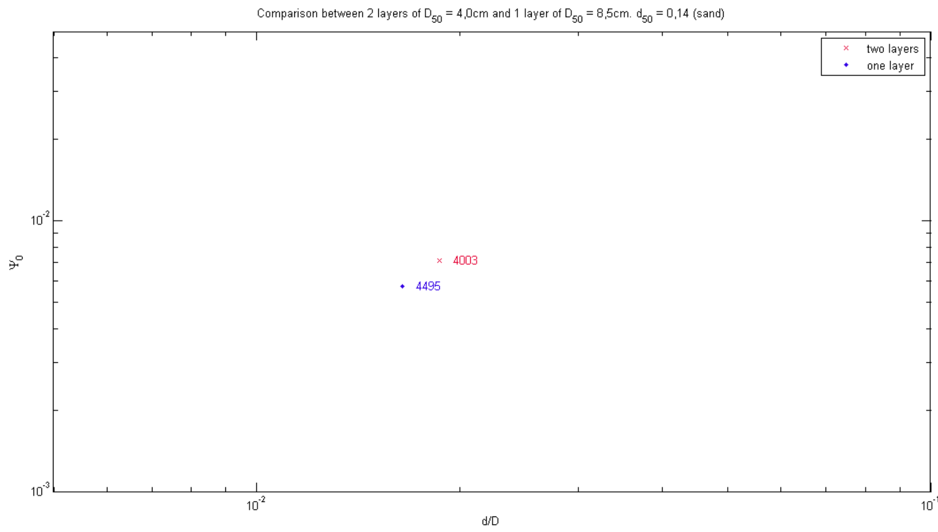



*Figure 6.20: Plot using $\psi_0$ and $A_0$ of test 18 of the case 7 and test 25 of the case 10.*

Looking at the figures 6.18, 6.19 and 6.20 the following comments can be observed: when there are two layers a higher mobility number is required than for one layer of the same size. The reason is that with one layer, the holes between the stones are bigger than in the case of two layers.

The recirculation of the water in between the stones in the case of two layers is much more difficult and it finds more obstacles to arrive to the main flow over the protection compared with the case of one layer of stones of the same size. (see figure 6.20).

Therefore, the suction in the case of two layers is more complicated than in the case of one layer.

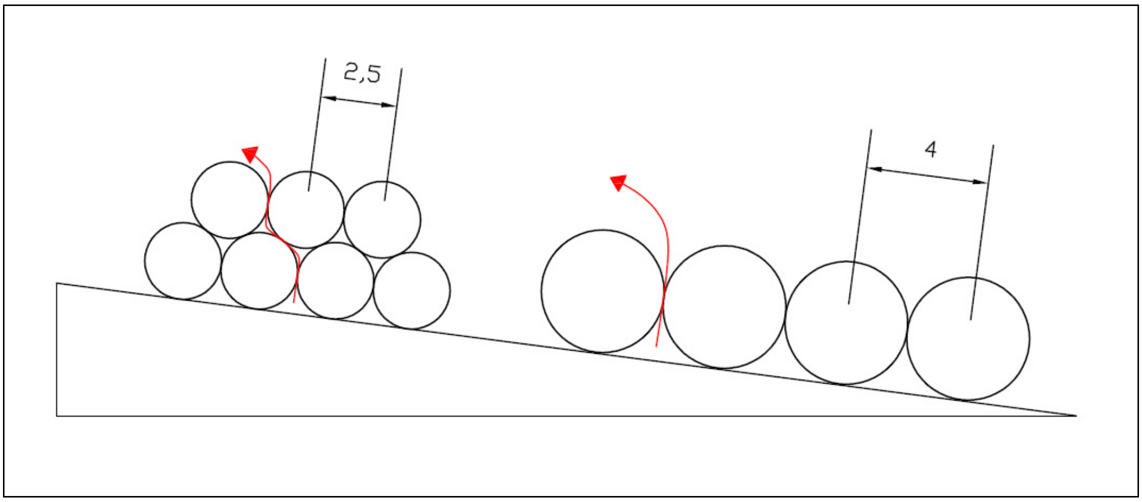



*Figure 6,21: Recirculation of the water and/or sediment in between the scour protection in the cases of two layers and one layer of protection.*

## *6.5 The practical application of the critical suction curve - an example*

A concrete breakwater parallel to the coast line needs to be protected from scour in its foundation because of some large waves before they reach the breakwater. The waves, which are breaking before the breakwater, have a period of T = 7s and a height of $H_0$ = 1.6 m. This gives a breaking parameter:

$$A = \frac{T^2 g}{H} = \frac{49s^2 \cdot 9.81\frac{m}{s^2}}{1.6m} = 300.43 \approx 300$$

The following scenario can be studied.

### 6.5.1 Scenario

A single rip-rap layer is placed around the breakwater. Because of the situation before the breakwater was established, the sediment changes along the breakwater from a sand size of $d_{50}$ = 0:2 mm to $d_{50}$ = 3 mm. It is found that the breakwater can be split in 3 regions depending on the sand size:

- $d_{50(1)}$ = 0.5 mm
- $d_{50(2)}$ = 0.8 mm

- $d_{50(3)}$ = 2.0 mm

All the sediment has a specific gravity of s = 2:65.

$$\Psi = \frac{(H/T)^2}{g(s-1)d}$$

The mobility number $\psi_0$ gives:

$\psi_{0(1)}$ = 6.45

$\psi_{0(2)}$ = 4.03

$\psi_{0(3)}$ = 1.61

Checking the figure 6.7, the d/D for critical suction in each of the 3 regions can be found, looking at the curve for A0≈300 and they are around:

$d/D_{(1)}$ = 0.0010

$d/D_{(2)}$ = 0.00105

$d/D_{(3)}$ = 0.0018

Then, the thickness of the layer for each zone:

$D_{(1)}$ = 500 mm. = 0.5 m.
$D_{(2)}$ = 763 mm. = 0.77 m.
$D_{(3)}$ = 1111 mm. = 1.12 m.

# 7. SUMMARY AND CONCLUSIONS

1. For different values of the wave breaking parameter *A* (different $H_0$ and *T*), *d/D*, and mobility number $\psi_0$; the critical mobility number $\psi_0$, that induces suction, has been determined for a 1:13 slope and one or two layers of stones protection, See figures 6.2, 6.3, 6.10 and 6.11.

2. Comparison diagrams for critical suction for one and two layers cases have been worked out, finding that for two layers the suction is much more difficult to happen.

3. Comparison diagrams for critical suction for two different slopes: 1:13 and 1:30 have been plotted in the case of one layer of stones protection. It has been found out that both slopes have a similar behaviour, but with a slight displacement. See figures 6.7, 6.8, 6.15, 6.16 and 6.17. From here it is possible to conclude that the slope effect is considerable in the mobility number. Therefore, for the same value of the breaking parameter (*A*), smoother slopes require higher mobility numbers to induce suction than steeper slopes.

4. One of the main contributions of these experiments is that the following question has been answered: "*Has one layer of protection the same effect as two layers of protection with half size stones?*" For example: is it the same to use one layer of 4 cm. or two layers of 2,5 cm. both with a $D_{50}$ = 4 cm.? (See figure 6.21 for a visual example).

It has been found out that the use of two layers protects better than one layer of the same size due to the difficulty of the recirculation of the water in between the stones in the two layers case. See figures 6.18, 6.19 and 6.20.

5. An important vagueness of this research is the fact that it was carried out using regular waves (monochromatic waves). In nature wave usually are random and irregular. Applications of these results to natural conditions must be subjected to validation for specific conditions. Therefore a suggestion for a possible work for future is to carry out these experiments with irregular waves and if possible at a higher scale for longitudes ($h_0$, $H_0$ and $D_{50}$).

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# APPENDIX A

| CASE 1 | | STONES | | | SEDIMENT | | | | FLOW PROPERTIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test number | date | D [cm] | Number of layers | Material | Material | d [cm] | $s=\rho_s/\rho$ | d/D | Water depth [cm] | Hin [m] | $H_{g1}$ [cm] | $H_0$ [cm] | $H_{mes}$ [cm] | T [s] | Suction? Yes=s NO=n | hole number of the section | $\psi_{in}$ | $\psi_{g1}$ | $\psi_0$ | $\psi_{mes}$ | $A_{in}$ | $A_{g1}$ | $A_0$ | $A_{mes}$ | L to breaking [m] |
| | 27/3/2009 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 27/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,045 | 4,2 | 5,6 | 4,2 | 5,0 | n | 1 | 0,0017 | 0,0015 | 0,0026 | 0,0014 | 5450 | 5802 | 4378 | 5901 | 4,34 |
| 1 | 27/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,045 | 4,2 | 5,6 | 4,2 | 5,0 | n | 2 | 0,0017 | 0,0015 | 0,0026 | 0,0014 | 5450 | 5802 | 4378 | 5901 | 4,34 |
| 1 | 27/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,045 | 4,2 | 5,6 | 4,2 | 5,0 | n | 3 | 0,0017 | 0,0015 | 0,0026 | 0,0014 | 5450 | 5802 | 4378 | 5901 | 4,34 |
| 1 | 27/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,045 | 4,2 | 5,6 | 4,2 | 5,0 | n | 4 | 0,0017 | 0,0015 | 0,0026 | 0,0014 | 5450 | 5802 | 4378 | 5901 | 4,34 |
| 2 | 27/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,050 | 4,9 | 6,0 | 5,1 | 5,0 | n | 1 | 0,0021 | 0,0019 | 0,0029 | 0,0021 | 4905 | 5050 | 4107 | 4843 | 4,4 |
| 2 | 27/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,050 | 4,9 | 6,0 | 5,1 | 5,0 | n | 2 | 0,0021 | 0,0019 | 0,0029 | 0,0021 | 4905 | 5050 | 4107 | 4843 | 4,4 |
| 2 | 27/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,050 | 4,9 | 6,0 | 5,1 | 5,0 | n | 3 | 0,0021 | 0,0019 | 0,0029 | 0,0021 | 4905 | 5050 | 4107 | 4843 | 4,4 |
| 2 | 27/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,050 | 4,9 | 6,0 | 5,1 | 5,0 | n | 4 | 0,0021 | 0,0019 | 0,0029 | 0,0021 | 4905 | 5050 | 4107 | 4843 | 4,4 |
| 3 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,055 | 5,7 | 3,6 | 4,2 | 5,2 | n | 1 | 0,0023 | 0,0025 | 0,0010 | 0,0013 | 4823 | 4670 | 7469 | 6381 | 4,34 |
| 3 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,055 | 5,7 | 3,6 | 4,2 | 5,2 | n | 2 | 0,0023 | 0,0025 | 0,0010 | 0,0013 | 4823 | 4670 | 7469 | 6381 | 4,34 |
| 3 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,055 | 5,7 | 3,6 | 4,2 | 5,2 | n | 3 | 0,0023 | 0,0025 | 0,0010 | 0,0013 | 4823 | 4670 | 7469 | 6381 | 4,34 |
| 3 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,055 | 5,7 | 3,6 | 4,2 | 5,2 | n | 4 | 0,0023 | 0,0025 | 0,0010 | 0,0013 | 4823 | 4670 | 7469 | 6381 | 4,34 |
| 4 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,060 | 6,2 | 3,6 | 4,7 | 5,3 | n | 1 | 0,0026 | 0,0028 | 0,0009 | 0,0016 | 4593 | 4435 | 7757 | 5829 | 4,4 |
| 4 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,060 | 6,2 | 3,6 | 4,7 | 5,3 | s | 2 | 0,0026 | 0,0028 | 0,0009 | 0,0016 | 4593 | 4435 | 7757 | 5829 | 4,4 |
| 4 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,060 | 6,2 | 3,6 | 4,7 | 5,3 | n | 3 | 0,0026 | 0,0028 | 0,0009 | 0,0016 | 4593 | 4435 | 7757 | 5829 | 4,4 |
| 4 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37,5 | 0,060 | 6,2 | 3,6 | 4,7 | 5,3 | n | 4 | 0,0026 | 0,0028 | 0,0009 | 0,0016 | 4593 | 4435 | 7757 | 5829 | 4,4 |
| 5 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,065 | 7,5 | 3,4 | 5,5 | 5,5 | n | 1 | 0,0029 | 0,0038 | 0,0008 | 0,0021 | 4565 | 3947 | 8850 | 5394 | 4,34 |
| 5 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,065 | 7,5 | 3,4 | 5,5 | 5,5 | s | 2 | 0,0029 | 0,0038 | 0,0008 | 0,0021 | 4565 | 3947 | 8850 | 5394 | 4,34 |
| 5 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,065 | 7,5 | 3,4 | 5,5 | 5,5 | s | 3 | 0,0029 | 0,0038 | 0,0008 | 0,0021 | 4565 | 3947 | 8850 | 5394 | 4,34 |
| 5 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,065 | 7,5 | 3,4 | 5,5 | 5,5 | n | 4 | 0,0029 | 0,0038 | 0,0008 | 0,0021 | 4565 | 3947 | 8850 | 5394 | 4,34 |
| 6 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36,5 | 0,070 | 8,9 | 3,6 | 6,8 | 5,7 | s | 1 | 0,0031 | 0,0050 | 0,0008 | 0,0029 | 4553 | 3588 | 8969 | 4691 | 4,4 |
| 6 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36,5 | 0,070 | 8,9 | 3,6 | 6,8 | 5,7 | s | 2 | 0,0031 | 0,0050 | 0,0008 | 0,0029 | 4553 | 3588 | 8969 | 4691 | 4,4 |
| 6 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36,5 | 0,070 | 8,9 | 3,6 | 6,8 | 5,7 | s | 3 | 0,0031 | 0,0050 | 0,0008 | 0,0029 | 4553 | 3588 | 8969 | 4691 | 4,4 |
| 6 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36,5 | 0,070 | 8,9 | 3,6 | 6,8 | 5,7 | s | 4 | 0,0031 | 0,0050 | 0,0008 | 0,0029 | 4553 | 3588 | 8969 | 4691 | 4,4 |
| 7 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37 | 0,040 | 4,5 | 3,4 | 4,2 | 3,0 | n | 1 | 0,0037 | 0,0046 | 0,0027 | 0,0040 | 2207 | 1975 | 2573 | 2104 | 4,3 |
| 7 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37 | 0,040 | 4,5 | 3,4 | 4,2 | 3,0 | n | 2 | 0,0037 | 0,0046 | 0,0027 | 0,0040 | 2207 | 1975 | 2573 | 2104 | 4,3 |
| 7 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37 | 0,040 | 4,5 | 3,4 | 4,2 | 3,0 | n | 3 | 0,0037 | 0,0046 | 0,0027 | 0,0040 | 2207 | 1975 | 2573 | 2104 | 4,3 |
| 7 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37 | 0,040 | 4,5 | 3,4 | 4,2 | 3,0 | n | 4 | 0,0037 | 0,0046 | 0,0027 | 0,0040 | 2207 | 1975 | 2573 | 2104 | 4,3 |
| 8 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,050 | 3,0 | 5,0 | 5,4 | 3,2 | n | 1 | 0,0050 | 0,0018 | 0,0050 | 0,0059 | 2009 | 3328 | 2008 | 1856 | 4,25 |
| 8 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,050 | 3,0 | 5,0 | 5,4 | 3,2 | n | 2 | 0,0050 | 0,0018 | 0,0050 | 0,0059 | 2009 | 3328 | 2008 | 1856 | 4,25 |
| 8 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,050 | 3,0 | 5,0 | 5,4 | 3,2 | n | 3 | 0,0050 | 0,0018 | 0,0050 | 0,0059 | 2009 | 3328 | 2008 | 1856 | 4,25 |
| 8 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,050 | 3,0 | 5,0 | 5,4 | 3,2 | n | 4 | 0,0050 | 0,0018 | 0,0050 | 0,0059 | 2009 | 3328 | 2008 | 1856 | 4,25 |
| 9 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,060 | 3,8 | 5,6 | 8,3 | 3,4 | s | 1 | 0,0064 | 0,0026 | 0,0056 | 0,0124 | 1890 | 2962 | 2021 | 1360 | 4,25 |
| 9 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,060 | 3,8 | 5,6 | 8,3 | 3,4 | s | 2 | 0,0064 | 0,0026 | 0,0056 | 0,0124 | 1890 | 2962 | 2021 | 1360 | 4,25 |
| 9 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,060 | 3,8 | 5,6 | 8,3 | 3,4 | n | 3 | 0,0064 | 0,0026 | 0,0056 | 0,0124 | 1890 | 2962 | 2021 | 1360 | 4,25 |
| 9 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,060 | 3,8 | 5,6 | 8,3 | 3,4 | n | 4 | 0,0064 | 0,0026 | 0,0056 | 0,0124 | 1890 | 2962 | 2021 | 1360 | 4,25 |
| 10 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36,5 | 0,065 | 5,7 | 5,2 | 8,6 | 3,5 | s | 1 | 0,0071 | 0,0056 | 0,0046 | 0,0123 | 1849 | 2090 | 2301 | 1405 | 4,25 |
| 10 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36,5 | 0,065 | 5,7 | 5,2 | 8,6 | 3,5 | s | 2 | 0,0071 | 0,0056 | 0,0046 | 0,0123 | 1849 | 2090 | 2301 | 1405 | 4,25 |
| 10 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36,5 | 0,065 | 5,7 | 5,2 | 8,6 | 3,5 | s | 3 | 0,0071 | 0,0056 | 0,0046 | 0,0123 | 1849 | 2090 | 2301 | 1405 | 4,25 |
| 10 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36,5 | 0,065 | 5,7 | 5,2 | 8,6 | 3,5 | s | 4 | 0,0071 | 0,0056 | 0,0046 | 0,0123 | 1849 | 2090 | 2301 | 1405 | 4,25 |
| 11 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37 | 0,050 | 3,5 | 3,8 | 4,8 | 1,0 | n | 1 | 0,0515 | 0,0256 | 0,0302 | 0,0473 | 196 | 278 | 256 | 205 | 4,1 |
| 11 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37 | 0,050 | 3,5 | 3,8 | 4,8 | 1,0 | n | 2 | 0,0515 | 0,0256 | 0,0302 | 0,0473 | 196 | 278 | 256 | 205 | 4,1 |
| 11 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37 | 0,050 | 3,5 | 3,8 | 4,8 | 1,0 | n | 3 | 0,0515 | 0,0256 | 0,0302 | 0,0473 | 196 | 278 | 256 | 205 | 4,1 |
| 11 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 37 | 0,050 | 3,5 | 3,8 | 4,8 | 1,0 | n | 4 | 0,0515 | 0,0256 | 0,0302 | 0,0473 | 196 | 278 | 256 | 205 | 4,1 |
| 12 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,060 | 4,8 | 4,6 | 5,6 | 1,1 | n | 1 | 0,0613 | 0,0398 | 0,0353 | 0,0537 | 198 | 245 | 261 | 211 | 4,1 |
| 12 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,060 | 4,8 | 4,6 | 5,6 | 1,1 | n | 2 | 0,0613 | 0,0398 | 0,0353 | 0,0537 | 198 | 245 | 261 | 211 | 4,1 |
| 12 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,060 | 4,8 | 4,6 | 5,6 | 1,1 | n | 3 | 0,0613 | 0,0398 | 0,0353 | 0,0537 | 198 | 245 | 261 | 211 | 4,1 |
| 12 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 36 | 0,060 | 4,8 | 4,6 | 5,6 | 1,1 | n | 4 | 0,0613 | 0,0398 | 0,0353 | 0,0537 | 198 | 245 | 261 | 211 | 4,1 |
| 13 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,070 | 5,6 | 5,8 | 6,8 | 1,2 | n | 1 | 0,0701 | 0,0445 | 0,0479 | 0,0654 | 202 | 253 | 244 | 209 | 4,1 |
| 13 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,070 | 5,6 | 5,8 | 6,8 | 1,2 | n | 2 | 0,0701 | 0,0445 | 0,0479 | 0,0654 | 202 | 253 | 244 | 209 | 4,1 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,070 | 5,6 | 5,8 | 6,8 | 1,2 | n | 3 | 0,0701 | 0,0445 | 0,0479 | 0,0654 | 202 | 253 | 244 | 209 | 4,1 |
| 13 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,070 | 5,6 | 5,8 | 6,8 | 1,2 | n | 4 | 0,0701 | 0,0445 | 0,0479 | 0,0654 | 202 | 253 | 244 | 209 | 4,1 |
| 14 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,080 | 6,7 | 6,2 | 7,0 | 1,3 | s | 1 | 0,0780 | 0,0540 | 0,0461 | 0,0592 | 207 | 249 | 270 | 238 | 4,1 |
| 14 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,080 | 6,7 | 6,2 | 7,0 | 1,3 | n | 2 | 0,0780 | 0,0540 | 0,0461 | 0,0592 | 207 | 249 | 270 | 238 | 4,1 |
| 14 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,080 | 6,7 | 6,2 | 7,0 | 1,3 | n | 3 | 0,0780 | 0,0540 | 0,0461 | 0,0592 | 207 | 249 | 270 | 238 | 4,1 |
| 14 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,080 | 6,7 | 6,2 | 7,0 | 1,3 | n | 4 | 0,0780 | 0,0540 | 0,0461 | 0,0592 | 207 | 249 | 270 | 238 | 4,1 |
| 15 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 34,5 | 0,090 | 7,0 | 6,7 | 7,3 | 1,5 | s | 1 | 0,0741 | 0,0450 | 0,0409 | 0,0491 | 245 | 315 | 330 | 301 | 4,1 |
| 15 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 34,5 | 0,090 | 7,0 | 6,7 | 7,3 | 1,5 | s | 2 | 0,0741 | 0,0450 | 0,0409 | 0,0491 | 245 | 315 | 330 | 301 | 4,1 |
| 15 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 34,5 | 0,090 | 7,0 | 6,7 | 7,3 | 1,5 | n | 3 | 0,0741 | 0,0450 | 0,0409 | 0,0491 | 245 | 315 | 330 | 301 | 4,1 |
| 15 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 34,5 | 0,090 | 7,0 | 6,7 | 7,3 | 1,5 | n | 4 | 0,0741 | 0,0450 | 0,0409 | 0,0491 | 245 | 315 | 330 | 301 | 4,1 |
| 16 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,100 | 7,9 | 7,1 | 6,9 | 1,5 | s | 1 | 0,0915 | 0,0577 | 0,0458 | 0,0439 | 221 | 278 | 312 | 319 | 4,1 |
| 16 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,100 | 7,9 | 7,1 | 6,9 | 1,5 | s | 2 | 0,0915 | 0,0577 | 0,0458 | 0,0439 | 221 | 278 | 312 | 319 | 4,1 |
| 16 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,100 | 7,9 | 7,1 | 6,9 | 1,5 | s | 3 | 0,0915 | 0,0577 | 0,0458 | 0,0439 | 221 | 278 | 312 | 319 | 4,1 |
| 16 | 30/3/2009 | 2,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,12 | 35 | 0,100 | 7,9 | 7,1 | 6,9 | 1,5 | s | 4 | 0,0915 | 0,0577 | 0,0458 | 0,0439 | 221 | 278 | 312 | 319 | 4,1 |

| CASE 2 | | STONES | | | SEDIMENT | | | | FLOW PROPERTIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test number | date | D [cm] | Number of layers | Material | Material | d [cm] | $s=\rho_s/\rho$ | d/D | Water depth [cm] | Hin [m] | $H_{g1}$ [cm] | $H_0$ [cm] | $H_{mes}$ [cm] | T [s] | Suspicion? Yes=s NO=n | hole number of the section | $\psi_{in}$ | $\psi_{g1}$ | $\psi_0$ | $\psi_{mes}$ | $A_{in}$ | $A_{g1}$ | $A_0$ | $A_{mes}$ | L to breaking [m] |
| | 02/04/2009 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,030 | 4,5 | 4,1 | 4,6 | 4,8 | n | 1 | 0,0017 | 0,0040 | 0,0032 | 0,0041 | 7534 | 4972 | 5544 | 4895 | 4,35 |
| 1 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,030 | 4,5 | 4,1 | 4,6 | 4,8 | n | 2 | 0,0017 | 0,0040 | 0,0032 | 0,0041 | 7534 | 4972 | 5544 | 4895 | 4,35 |
| 1 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,030 | 4,5 | 4,1 | 4,6 | 4,8 | n | 3 | 0,0017 | 0,0040 | 0,0032 | 0,0041 | 7534 | 4972 | 5544 | 4895 | 4,35 |
| 1 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,030 | 4,5 | 4,1 | 4,6 | 4,8 | n | 4 | 0,0017 | 0,0040 | 0,0032 | 0,0041 | 7534 | 4972 | 5544 | 4895 | 4,35 |
| 2 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,045 | 5,1 | 3,8 | 5,7 | 5,0 | n | 1 | 0,0036 | 0,0045 | 0,0026 | 0,0057 | 5450 | 4848 | 6448 | 4300 | 4,35 |
| 2 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,045 | 5,1 | 3,8 | 5,7 | 5,0 | s | 2 | 0,0036 | 0,0045 | 0,0026 | 0,0057 | 5450 | 4848 | 6448 | 4300 | 4,35 |
| 2 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,045 | 5,1 | 3,8 | 5,7 | 5,0 | n | 3 | 0,0036 | 0,0045 | 0,0026 | 0,0057 | 5450 | 4848 | 6448 | 4300 | 4,35 |
| 2 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,045 | 5,1 | 3,8 | 5,7 | 5,0 | n | 4 | 0,0036 | 0,0045 | 0,0026 | 0,0057 | 5450 | 4848 | 6448 | 4300 | 4,35 |
| 3 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,050 | 5,9 | 2,8 | 6,4 | 5,2 | s | 1 | 0,0041 | 0,0057 | 0,0013 | 0,0067 | 5305 | 4478 | 9410 | 4136 | 4,35 |
| 3 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,050 | 5,9 | 2,8 | 6,4 | 5,2 | s | 2 | 0,0041 | 0,0057 | 0,0013 | 0,0067 | 5305 | 4478 | 9410 | 4136 | 4,35 |
| 3 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,050 | 5,9 | 2,8 | 6,4 | 5,2 | n | 3 | 0,0041 | 0,0057 | 0,0013 | 0,0067 | 5305 | 4478 | 9410 | 4136 | 4,35 |
| 3 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,050 | 5,9 | 2,8 | 6,4 | 5,2 | n | 4 | 0,0041 | 0,0057 | 0,0013 | 0,0067 | 5305 | 4478 | 9410 | 4136 | 4,35 |
| 4 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,055 | 4,1 | 3,3 | 3,1 | 5,4 | s | 1 | 0,0046 | 0,0025 | 0,0017 | 0,0015 | 5201 | 7003 | 8635 | 9213 | 4,35 |
| 4 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,055 | 4,1 | 3,3 | 3,1 | 5,4 | s | 2 | 0,0046 | 0,0025 | 0,0017 | 0,0015 | 5201 | 7003 | 8635 | 9213 | 4,35 |
| 4 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,055 | 4,1 | 3,3 | 3,1 | 5,4 | s | 3 | 0,0046 | 0,0025 | 0,0017 | 0,0015 | 5201 | 7003 | 8635 | 9213 | 4,35 |
| 4 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 37,5 | 0,055 | 4,1 | 3,3 | 3,1 | 5,4 | s | 4 | 0,0046 | 0,0025 | 0,0017 | 0,0015 | 5201 | 7003 | 8635 | 9213 | 4,35 |
| 5 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,030 | 3,1 | 2,4 | 1,9 | 3,0 | n | 1 | 0,0044 | 0,0047 | 0,0029 | 0,0018 | 2943 | 2854 | 3636 | 4654 | 4,25 |
| 5 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,030 | 3,1 | 2,4 | 1,9 | 3,0 | n | 2 | 0,0044 | 0,0047 | 0,0029 | 0,0018 | 2943 | 2854 | 3636 | 4654 | 4,25 |
| 5 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,030 | 3,1 | 2,4 | 1,9 | 3,0 | n | 3 | 0,0044 | 0,0047 | 0,0029 | 0,0018 | 2943 | 2854 | 3636 | 4654 | 4,25 |
| 5 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,030 | 3,1 | 2,4 | 1,9 | 3,0 | n | 4 | 0,0044 | 0,0047 | 0,0029 | 0,0018 | 2943 | 2854 | 3636 | 4654 | 4,25 |
| 6 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,040 | 4,7 | 3,9 | 4,1 | 3,0 | s | 1 | 0,0078 | 0,0106 | 0,0074 | 0,0081 | 2207 | 1894 | 2270 | 2176 | 4,3 |
| 6 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,040 | 4,7 | 3,9 | 4,1 | 3,0 | s | 2 | 0,0078 | 0,0106 | 0,0074 | 0,0081 | 2207 | 1894 | 2270 | 2176 | 4,3 |
| 6 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,040 | 4,7 | 3,9 | 4,1 | 3,0 | n | 3 | 0,0078 | 0,0106 | 0,0074 | 0,0081 | 2207 | 1894 | 2270 | 2176 | 4,3 |
| 6 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,040 | 4,7 | 3,9 | 4,1 | 3,0 | n | 4 | 0,0078 | 0,0106 | 0,0074 | 0,0081 | 2207 | 1894 | 2270 | 2176 | 4,3 |
| 7 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,050 | 2,4 | 3,9 | 2,7 | 3,0 | s | 1 | 0,0123 | 0,0029 | 0,0076 | 0,0037 | 1766 | 3636 | 2247 | 3230 | 4,25 |
| 7 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,050 | 2,4 | 3,9 | 2,7 | 3,0 | s | 2 | 0,0123 | 0,0029 | 0,0076 | 0,0037 | 1766 | 3636 | 2247 | 3230 | 4,25 |
| 7 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,050 | 2,4 | 3,9 | 2,7 | 3,0 | s | 3 | 0,0123 | 0,0029 | 0,0076 | 0,0037 | 1766 | 3636 | 2247 | 3230 | 4,25 |
| 7 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,050 | 2,4 | 3,9 | 2,7 | 3,0 | s | 4 | 0,0123 | 0,0029 | 0,0076 | 0,0037 | 1766 | 3636 | 2247 | 3230 | 4,25 |
| 8 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,035 | 3,3 | 2,9 | 2,9 | 1,0 | n | 1 | 0,0541 | 0,0492 | 0,0362 | 0,0381 | 280 | 294 | 342 | 334 | 4,1 |
| 8 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,035 | 3,3 | 2,9 | 2,9 | 1,0 | n | 2 | 0,0541 | 0,0492 | 0,0362 | 0,0381 | 280 | 294 | 342 | 334 | 4,1 |
| 8 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,035 | 3,3 | 2,9 | 2,9 | 1,0 | n | 3 | 0,0541 | 0,0492 | 0,0362 | 0,0381 | 280 | 294 | 342 | 334 | 4,1 |
| 8 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,035 | 3,3 | 2,9 | 2,9 | 1,0 | n | 4 | 0,0541 | 0,0492 | 0,0362 | 0,0381 | 280 | 294 | 342 | 334 | 4,1 |
| 9 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,040 | 3,0 | 3,0 | 3,7 | 1,1 | s | 1 | 0,0584 | 0,0337 | 0,0330 | 0,0505 | 297 | 390 | 395 | 319 | 4,1 |
| 9 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,040 | 3,0 | 3,0 | 3,7 | 1,1 | s | 2 | 0,0584 | 0,0337 | 0,0330 | 0,0505 | 297 | 390 | 395 | 319 | 4,1 |
| 9 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,040 | 3,0 | 3,0 | 3,7 | 1,1 | s | 3 | 0,0584 | 0,0337 | 0,0330 | 0,0505 | 297 | 390 | 395 | 319 | 4,1 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36 | 0,040 | 3,0 | 3,0 | 3,7 | 1,1 | n | 4 | 0,0584 | 0,0337 | 0,0330 | 0,0505 | 297 | 390 | 395 | 319 | 4,1 |
| 10 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36,5 | 0,050 | 4,0 | 4,0 | 5,2 | 1,2 | s | 1 | 0,0766 | 0,0494 | 0,0495 | 0,0827 | 283 | 352 | 352 | 272 | 4,1 |
| 10 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36,5 | 0,050 | 4,0 | 4,0 | 5,2 | 1,2 | s | 2 | 0,0766 | 0,0494 | 0,0495 | 0,0827 | 283 | 352 | 352 | 272 | 4,1 |
| 10 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36,5 | 0,050 | 4,0 | 4,0 | 5,2 | 1,2 | s | 3 | 0,0766 | 0,0494 | 0,0495 | 0,0827 | 283 | 352 | 352 | 272 | 4,1 |
| 10 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36,5 | 0,050 | 4,0 | 4,0 | 5,2 | 1,2 | n | 4 | 0,0766 | 0,0494 | 0,0495 | 0,0827 | 283 | 352 | 352 | 272 | 4,1 |
| 11 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36,5 | 0,060 | 4,5 | 4,6 | 6,6 | 1,3 | s | 1 | 0,0940 | 0,0529 | 0,0553 | 0,1129 | 276 | 368 | 360 | 252 | 4,1 |
| 11 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36,5 | 0,060 | 4,5 | 4,6 | 6,6 | 1,3 | s | 2 | 0,0940 | 0,0529 | 0,0553 | 0,1129 | 276 | 368 | 360 | 252 | 4,1 |
| 11 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36,5 | 0,060 | 4,5 | 4,6 | 6,6 | 1,3 | s | 3 | 0,0940 | 0,0529 | 0,0553 | 0,1129 | 276 | 368 | 360 | 252 | 4,1 |
| 11 | 02/04/2009 | 2,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,056 | 36,5 | 0,060 | 4,5 | 4,6 | 6,6 | 1,3 | s | 4 | 0,0940 | 0,0529 | 0,0553 | 0,1129 | 276 | 368 | 360 | 252 | 4,1 |

| CASE 3 | | STONES | | | SEDIMENT | | | | FLOW PROPERTIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test number | date | D [cm] | Number of layers | Material | Material | d [cm] | $s=\rho_s/\rho$ | d/D | Water depth [cm] | Hin [m] | $H_{g1}$ [cm] | $H_0$ [cm] | $H_{mes}$ [cm] | T [s] | Suction? Yes=s NO=n | hole number of the section | $\psi_{in}$ | $\psi_{g1}$ | $\psi_0$ | $\psi_{mes}$ | $A_{in}$ | $A_{g1}$ | $A_0$ | $A_{mes}$ | L to breaking [m] |
| | 03/04/2009 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,040 | 3,4 | 3,7 | 3,6 | 5,0 | n | 1 | 0,0028 | 0,0020 | 0,0024 | 0,0023 | 6131 | 7273 | 6665 | 6784 | 4,34 |
| 1 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,040 | 3,4 | 3,7 | 3,6 | 5,0 | n | 2 | 0,0028 | 0,0020 | 0,0024 | 0,0023 | 6131 | 7273 | 6665 | 6784 | 4,34 |
| 1 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,040 | 3,4 | 3,7 | 3,6 | 5,0 | n | 3 | 0,0028 | 0,0020 | 0,0024 | 0,0023 | 6131 | 7273 | 6665 | 6784 | 4,34 |
| 1 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,040 | 3,4 | 3,7 | 3,6 | 5,0 | n | 4 | 0,0028 | 0,0020 | 0,0024 | 0,0023 | 6131 | 7273 | 6665 | 6784 | 4,34 |
| 2 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,055 | 5,2 | 3,8 | 4,5 | 5,2 | n | 1 | 0,0049 | 0,0044 | 0,0024 | 0,0034 | 4823 | 5134 | 6961 | 5841 | 4,4 |
| 2 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,055 | 5,2 | 3,8 | 4,5 | 5,2 | n | 2 | 0,0049 | 0,0044 | 0,0024 | 0,0034 | 4823 | 5134 | 6961 | 5841 | 4,4 |
| 2 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,055 | 5,2 | 3,8 | 4,5 | 5,2 | n | 3 | 0,0049 | 0,0044 | 0,0024 | 0,0034 | 4823 | 5134 | 6961 | 5841 | 4,4 |
| 2 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,055 | 5,2 | 3,8 | 4,5 | 5,2 | n | 4 | 0,0049 | 0,0044 | 0,0024 | 0,0034 | 4823 | 5134 | 6961 | 5841 | 4,4 |
| 3 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,065 | 6,5 | 3,5 | 6,3 | 5,4 | n | 1 | 0,0064 | 0,0064 | 0,0019 | 0,0060 | 4401 | 4391 | 8079 | 4546 | 4,34 |
| 3 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,065 | 6,5 | 3,5 | 6,3 | 5,4 | n | 2 | 0,0064 | 0,0064 | 0,0019 | 0,0060 | 4401 | 4391 | 8079 | 4546 | 4,34 |
| 3 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,065 | 6,5 | 3,5 | 6,3 | 5,4 | n | 3 | 0,0064 | 0,0064 | 0,0019 | 0,0060 | 4401 | 4391 | 8079 | 4546 | 4,34 |
| 3 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,065 | 6,5 | 3,5 | 6,3 | 5,4 | n | 4 | 0,0064 | 0,0064 | 0,0019 | 0,0060 | 4401 | 4391 | 8079 | 4546 | 4,34 |
| 4 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,075 | 7,6 | 3,9 | 6,5 | 5,4 | n | 1 | 0,0085 | 0,0088 | 0,0023 | 0,0064 | 3814 | 3744 | 7329 | 4401 | 4,4 |
| 4 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,075 | 7,6 | 3,9 | 6,5 | 5,4 | n | 2 | 0,0085 | 0,0088 | 0,0023 | 0,0064 | 3814 | 3744 | 7329 | 4401 | 4,4 |
| 4 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,075 | 7,6 | 3,9 | 6,5 | 5,4 | s | 3 | 0,0085 | 0,0088 | 0,0023 | 0,0064 | 3814 | 3744 | 7329 | 4401 | 4,4 |
| 4 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,075 | 7,6 | 3,9 | 6,5 | 5,4 | n | 4 | 0,0085 | 0,0088 | 0,0023 | 0,0064 | 3814 | 3744 | 7329 | 4401 | 4,4 |
| 5 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 38 | 0,085 | 9,6 | 4,2 | 7,2 | 5,5 | s | 1 | 0,0105 | 0,0134 | 0,0025 | 0,0076 | 3491 | 3098 | 7142 | 4107 | 4,34 |
| 5 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 38 | 0,085 | 9,6 | 4,2 | 7,2 | 5,5 | n | 2 | 0,0105 | 0,0134 | 0,0025 | 0,0076 | 3491 | 3098 | 7142 | 4107 | 4,34 |
| 5 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 38 | 0,085 | 9,6 | 4,2 | 7,2 | 5,5 | s | 3 | 0,0105 | 0,0134 | 0,0025 | 0,0076 | 3491 | 3098 | 7142 | 4107 | 4,34 |
| 5 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 38 | 0,085 | 9,6 | 4,2 | 7,2 | 5,5 | n | 4 | 0,0105 | 0,0134 | 0,0025 | 0,0076 | 3491 | 3098 | 7142 | 4107 | 4,34 |
| 6 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,100 | 10,1 | 6,1 | 9,0 | 5,7 | s | 1 | 0,0136 | 0,0138 | 0,0050 | 0,0111 | 3187 | 3157 | 5234 | 3530 | 4,4 |
| 6 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,100 | 10,1 | 6,1 | 9,0 | 5,7 | s | 2 | 0,0136 | 0,0138 | 0,0050 | 0,0111 | 3187 | 3157 | 5234 | 3530 | 4,4 |
| 6 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,100 | 10,1 | 6,1 | 9,0 | 5,7 | s | 3 | 0,0136 | 0,0138 | 0,0050 | 0,0111 | 3187 | 3157 | 5234 | 3530 | 4,4 |
| 6 | 03/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,100 | 10,1 | 6,1 | 9,0 | 5,7 | s | 4 | 0,0136 | 0,0138 | 0,0050 | 0,0111 | 3187 | 3157 | 5234 | 3530 | 4,4 |
| 7 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,055 | 5,7 | 4,5 | 5,6 | 3,0 | n | 1 | 0,0148 | 0,0161 | 0,0100 | 0,0156 | 1605 | 1543 | 1952 | 1566 | 4,3 |
| 7 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,055 | 5,7 | 4,5 | 5,6 | 3,0 | n | 2 | 0,0148 | 0,0161 | 0,0100 | 0,0156 | 1605 | 1543 | 1952 | 1566 | 4,3 |
| 7 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,055 | 5,7 | 4,5 | 5,6 | 3,0 | n | 3 | 0,0148 | 0,0161 | 0,0100 | 0,0156 | 1605 | 1543 | 1952 | 1566 | 4,3 |
| 7 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,055 | 5,7 | 4,5 | 5,6 | 3,0 | n | 4 | 0,0148 | 0,0161 | 0,0100 | 0,0156 | 1605 | 1543 | 1952 | 1566 | 4,3 |
| 8 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,065 | 4,1 | 6,9 | 6,7 | 3,2 | n | 1 | 0,0182 | 0,0074 | 0,0203 | 0,0196 | 1545 | 2426 | 1462 | 1490 | 4,3 |
| 8 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,065 | 4,1 | 6,9 | 6,7 | 3,2 | n | 2 | 0,0182 | 0,0074 | 0,0203 | 0,0196 | 1545 | 2426 | 1462 | 1490 | 4,3 |
| 8 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,065 | 4,1 | 6,9 | 6,7 | 3,2 | n | 3 | 0,0182 | 0,0074 | 0,0203 | 0,0196 | 1545 | 2426 | 1462 | 1490 | 4,3 |
| 8 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,065 | 4,1 | 6,9 | 6,7 | 3,2 | n | 4 | 0,0182 | 0,0074 | 0,0203 | 0,0196 | 1545 | 2426 | 1462 | 1490 | 4,3 |
| 9 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,075 | 6,1 | 6,9 | 7,2 | 3,4 | s | 1 | 0,0215 | 0,0143 | 0,0180 | 0,0201 | 1512 | 1856 | 1650 | 1565 | 4,3 |
| 9 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,075 | 6,1 | 6,9 | 7,2 | 3,4 | s | 2 | 0,0215 | 0,0143 | 0,0180 | 0,0201 | 1512 | 1856 | 1650 | 1565 | 4,3 |
| 9 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,075 | 6,1 | 6,9 | 7,2 | 3,4 | n | 3 | 0,0215 | 0,0143 | 0,0180 | 0,0201 | 1512 | 1856 | 1650 | 1565 | 4,3 |
| 9 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,075 | 6,1 | 6,9 | 7,2 | 3,4 | n | 4 | 0,0215 | 0,0143 | 0,0180 | 0,0201 | 1512 | 1856 | 1650 | 1565 | 4,3 |
| 10 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,085 | 7,9 | 6,4 | 8,6 | 3,5 | s | 1 | 0,0260 | 0,0223 | 0,0149 | 0,0269 | 1414 | 1526 | 1870 | 1390 | 4,3 |
| 10 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,085 | 7,9 | 6,4 | 8,6 | 3,5 | s | 2 | 0,0260 | 0,0223 | 0,0149 | 0,0269 | 1414 | 1526 | 1870 | 1390 | 4,3 |
| 10 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,085 | 7,9 | 6,4 | 8,6 | 3,5 | s | 3 | 0,0260 | 0,0223 | 0,0149 | 0,0269 | 1414 | 1526 | 1870 | 1390 | 4,3 |
| 10 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,085 | 7,9 | 6,4 | 8,6 | 3,5 | n | 4 | 0,0260 | 0,0223 | 0,0149 | 0,0269 | 1414 | 1526 | 1870 | 1390 | 4,3 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 40 | 0,095 | 9,1 | 7,0 | 8,8 | 3,5 | s | 1 | 0,0325 | 0,0300 | 0,0174 | 0,0279 | 1265 | 1316 | 1727 | 1365 | 4,3 |
| 11 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 40 | 0,095 | 9,1 | 7,0 | 8,8 | 3,5 | s | 2 | 0,0325 | 0,0300 | 0,0174 | 0,0279 | 1265 | 1316 | 1727 | 1365 | 4,3 |
| 11 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 40 | 0,095 | 9,1 | 7,0 | 8,8 | 3,5 | s | 3 | 0,0325 | 0,0300 | 0,0174 | 0,0279 | 1265 | 1316 | 1727 | 1365 | 4,3 |
| 11 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 40 | 0,095 | 9,1 | 7,0 | 8,8 | 3,5 | s | 4 | 0,0325 | 0,0300 | 0,0174 | 0,0279 | 1265 | 1316 | 1727 | 1365 | 4,3 |
| 12 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,070 | 4,6 | 6,2 | 4,8 | 1,0 | n | 1 | 0,2162 | 0,0942 | 0,1697 | 0,1017 | 140 | 212 | 158 | 204 | 4,15 |
| 12 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,070 | 4,6 | 6,2 | 4,8 | 1,0 | n | 2 | 0,2162 | 0,0942 | 0,1697 | 0,1017 | 140 | 212 | 158 | 204 | 4,15 |
| 12 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,070 | 4,6 | 6,2 | 4,8 | 1,0 | n | 3 | 0,2162 | 0,0942 | 0,1697 | 0,1017 | 140 | 212 | 158 | 204 | 4,15 |
| 12 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,070 | 4,6 | 6,2 | 4,8 | 1,0 | n | 4 | 0,2162 | 0,0942 | 0,1697 | 0,1017 | 140 | 212 | 158 | 204 | 4,15 |
| 13 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,080 | 5,7 | 6,9 | 5,2 | 1,0 | n | 1 | 0,2824 | 0,1429 | 0,2104 | 0,1186 | 123 | 172 | 142 | 189 | 4,1 |
| 13 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,080 | 5,7 | 6,9 | 5,2 | 1,0 | n | 2 | 0,2824 | 0,1429 | 0,2104 | 0,1186 | 123 | 172 | 142 | 189 | 4,1 |
| 13 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,080 | 5,7 | 6,9 | 5,2 | 1,0 | n | 3 | 0,2824 | 0,1429 | 0,2104 | 0,1186 | 123 | 172 | 142 | 189 | 4,1 |
| 13 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,080 | 5,7 | 6,9 | 5,2 | 1,0 | n | 4 | 0,2824 | 0,1429 | 0,2104 | 0,1186 | 123 | 172 | 142 | 189 | 4,1 |
| 14 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 38 | 0,090 | 6,7 | 7,5 | 5,9 | 1,0 | n | 1 | 0,3574 | 0,2007 | 0,2475 | 0,1518 | 109 | 145 | 131 | 167 | 4,1 |
| 14 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 38 | 0,090 | 6,7 | 7,5 | 5,9 | 1,0 | n | 2 | 0,3574 | 0,2007 | 0,2475 | 0,1518 | 109 | 145 | 131 | 167 | 4,1 |
| 14 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 38 | 0,090 | 6,7 | 7,5 | 5,9 | 1,0 | n | 3 | 0,3574 | 0,2007 | 0,2475 | 0,1518 | 109 | 145 | 131 | 167 | 4,1 |
| 14 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 38 | 0,090 | 6,7 | 7,5 | 5,9 | 1,0 | n | 4 | 0,3574 | 0,2007 | 0,2475 | 0,1518 | 109 | 145 | 131 | 167 | 4,1 |
| 15 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,105 | 8,2 | 8,2 | 7,0 | 1,1 | n | 1 | 0,4021 | 0,2427 | 0,2459 | 0,1797 | 113 | 146 | 145 | 169 | 4,1 |
| 15 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,105 | 8,2 | 8,2 | 7,0 | 1,1 | n | 2 | 0,4021 | 0,2427 | 0,2459 | 0,1797 | 113 | 146 | 145 | 169 | 4,1 |
| 15 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,105 | 8,2 | 8,2 | 7,0 | 1,1 | n | 3 | 0,4021 | 0,2427 | 0,2459 | 0,1797 | 113 | 146 | 145 | 169 | 4,1 |
| 15 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,105 | 8,2 | 8,2 | 7,0 | 1,1 | n | 4 | 0,4021 | 0,2427 | 0,2459 | 0,1797 | 113 | 146 | 145 | 169 | 4,1 |
| 16 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,120 | 9,1 | 9,8 | 6,8 | 1,1 | s | 1 | 0,5252 | 0,3016 | 0,3519 | 0,1693 | 99 | 131 | 121 | 174 | 4,1 |
| 16 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,120 | 9,1 | 9,8 | 6,8 | 1,1 | n | 2 | 0,5252 | 0,3016 | 0,3519 | 0,1693 | 99 | 131 | 121 | 174 | 4,1 |
| 16 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,120 | 9,1 | 9,8 | 6,8 | 1,1 | n | 3 | 0,5252 | 0,3016 | 0,3519 | 0,1693 | 99 | 131 | 121 | 174 | 4,1 |
| 16 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39 | 0,120 | 9,1 | 9,8 | 6,8 | 1,1 | n | 4 | 0,5252 | 0,3016 | 0,3519 | 0,1693 | 99 | 131 | 121 | 174 | 4,1 |
| 17 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,130 | 10,2 | 10,3 | 7,1 | 1,1 | s | 1 | 0,6163 | 0,3787 | 0,3852 | 0,1844 | 91 | 116 | 115 | 167 | 4,1 |
| 17 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,130 | 10,2 | 10,3 | 7,1 | 1,1 | s | 2 | 0,6163 | 0,3787 | 0,3852 | 0,1844 | 91 | 116 | 115 | 167 | 4,1 |
| 17 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,130 | 10,2 | 10,3 | 7,1 | 1,1 | s | 3 | 0,6163 | 0,3787 | 0,3852 | 0,1844 | 91 | 116 | 115 | 167 | 4,1 |
| 17 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,130 | 10,2 | 10,3 | 7,1 | 1,1 | n | 4 | 0,6163 | 0,3787 | 0,3852 | 0,1844 | 91 | 116 | 115 | 167 | 4,1 |
| 18 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,140 | 11,0 | 11,1 | 6,7 | 1,1 | s | 1 | 0,7148 | 0,4400 | 0,4458 | 0,1614 | 85 | 108 | 107 | 178 | 4,1 |
| 18 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,140 | 11,0 | 11,1 | 6,7 | 1,1 | s | 2 | 0,7148 | 0,4400 | 0,4458 | 0,1614 | 85 | 108 | 107 | 178 | 4,1 |
| 18 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,140 | 11,0 | 11,1 | 6,7 | 1,1 | s | 3 | 0,7148 | 0,4400 | 0,4458 | 0,1614 | 85 | 108 | 107 | 178 | 4,1 |
| 18 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,140 | 11,0 | 11,1 | 6,7 | 1,1 | n | 4 | 0,7148 | 0,4400 | 0,4458 | 0,1614 | 85 | 108 | 107 | 178 | 4,1 |
| 19 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,150 | 11,8 | 11,8 | 6,1 | 1,1 | s | 1 | 0,8206 | 0,5094 | 0,5064 | 0,1360 | 79 | 100 | 101 | 194 | 4,1 |
| 19 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,150 | 11,8 | 11,8 | 6,1 | 1,1 | s | 2 | 0,8206 | 0,5094 | 0,5064 | 0,1360 | 79 | 100 | 101 | 194 | 4,1 |
| 19 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,150 | 11,8 | 11,8 | 6,1 | 1,1 | s | 3 | 0,8206 | 0,5094 | 0,5064 | 0,1360 | 79 | 100 | 101 | 194 | 4,1 |
| 19 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,150 | 11,8 | 11,8 | 6,1 | 1,1 | n | 4 | 0,8206 | 0,5094 | 0,5064 | 0,1360 | 79 | 100 | 101 | 194 | 4,1 |
| 20 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,160 | 12,7 | 12,7 | 5,4 | 1,1 | s | 1 | 0,9336 | 0,5868 | 0,5863 | 0,1051 | 74 | 94 | 94 | 221 | 4,1 |
| 20 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,160 | 12,7 | 12,7 | 5,4 | 1,1 | s | 2 | 0,9336 | 0,5868 | 0,5863 | 0,1051 | 74 | 94 | 94 | 221 | 4,1 |
| 20 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,160 | 12,7 | 12,7 | 5,4 | 1,1 | s | 3 | 0,9336 | 0,5868 | 0,5863 | 0,1051 | 74 | 94 | 94 | 221 | 4,1 |
| 20 | 09/04/2009 | 4 | 2x2.5cm | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 39,5 | 0,160 | 12,7 | 12,7 | 5,4 | 1,1 | s | 4 | 0,9336 | 0,5868 | 0,5863 | 0,1051 | 74 | 94 | 94 | 221 | 4,1 |

| CASE 4 | | STONES | | | SEDIMENT | | | | FLOW PROPERTIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test number | date | D [cm] | Number of layers | Material | Material | d [cm] | $s=\rho_s/\rho$ | d/D | Water depth [cm] | Hin [m] | $H_{g1}$ [cm] | $H_0$ [cm] | $H_{mes}$ [cm] | T [s] | Suction? Yes=s NO=n | hole number of the section | $\psi_{in}$ | $\psi_{g1}$ | $\psi_0$ | $\psi_{mes}$ | $A_{in}$ | $A_{g1}$ | $A_0$ | $A_{mes}$ | L to breaking [m] |
| | 09/03/2009 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,050 | 2,6 | 3,3 | 5,7 | 2,4 | n | 1 | 0,0299 | 0,0251 | 0,0252 | 0,0338 | 1130 | 1233 | 1230 | 1063 | 4,3 |
| 1 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,050 | 2,6 | 3,3 | 5,7 | 2,4 | n | 2 | 0,0299 | 0,0251 | 0,0252 | 0,0338 | 1130 | 1233 | 1230 | 1063 | 4,3 |
| 1 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,050 | 2,6 | 3,3 | 5,7 | 2,4 | n | 3 | 0,0299 | 0,0251 | 0,0252 | 0,0338 | 1130 | 1233 | 1230 | 1063 | 4,3 |
| 1 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,050 | 2,6 | 3,3 | 5,7 | 2,4 | n | 4 | 0,0299 | 0,0251 | 0,0252 | 0,0338 | 1130 | 1233 | 1230 | 1063 | 4,3 |
| 2 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,050 | 4,4 | 4,4 | 5,1 | 2,5 | n | 1 | 0,0275 | 0,0158 | 0,0247 | 0,0293 | 1226 | 1618 | 1294 | 1189 | 4,3 |
| 2 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,050 | 4,4 | 4,4 | 5,1 | 2,5 | n | 2 | 0,0275 | 0,0158 | 0,0247 | 0,0293 | 1226 | 1618 | 1294 | 1189 | 4,3 |
| 2 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,050 | 4,4 | 4,4 | 5,1 | 2,5 | n | 3 | 0,0275 | 0,0158 | 0,0247 | 0,0293 | 1226 | 1618 | 1294 | 1189 | 4,3 |
| 2 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,050 | 4,4 | 4,4 | 5,1 | 2,5 | n | 4 | 0,0275 | 0,0158 | 0,0247 | 0,0293 | 1226 | 1618 | 1294 | 1189 | 4,3 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,055 | 3,7 | 4,6 | 4,9 | 2,5 | n | 1 | 0,0333 | 0,0161 | 0,0265 | 0,0323 | 1115 | 1603 | 1249 | 1132 | 4,3 |
| 3 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,055 | 3,7 | 4,6 | 4,9 | 2,5 | s | 2 | 0,0333 | 0,0161 | 0,0265 | 0,0323 | 1115 | 1603 | 1249 | 1132 | 4,3 |
| 3 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,055 | 3,7 | 4,6 | 4,9 | 2,5 | s | 3 | 0,0333 | 0,0161 | 0,0265 | 0,0323 | 1115 | 1603 | 1249 | 1132 | 4,3 |
| 3 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,055 | 3,7 | 4,6 | 4,9 | 2,5 | n | 4 | 0,0333 | 0,0161 | 0,0265 | 0,0323 | 1115 | 1603 | 1249 | 1132 | 4,3 |
| 4 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,060 | 3,7 | 4,7 | 5,2 | 2,6 | n | 1 | 0,0366 | 0,0128 | 0,0175 | 0,0438 | 1105 | 1867 | 1599 | 1011 | 4,3 |
| 4 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,060 | 3,7 | 4,7 | 5,2 | 2,6 | s | 2 | 0,0366 | 0,0128 | 0,0175 | 0,0438 | 1105 | 1867 | 1599 | 1011 | 4,3 |
| 4 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,060 | 3,7 | 4,7 | 5,2 | 2,6 | s | 3 | 0,0366 | 0,0128 | 0,0175 | 0,0438 | 1105 | 1867 | 1599 | 1011 | 4,3 |
| 4 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,060 | 3,7 | 4,7 | 5,2 | 2,6 | n | 4 | 0,0366 | 0,0128 | 0,0175 | 0,0438 | 1105 | 1867 | 1599 | 1011 | 4,3 |
| 5 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,065 | 3,0 | 3,9 | 6,2 | 2,7 | s | 1 | 0,0399 | 0,0328 | 0,0159 | 0,0626 | 1100 | 1213 | 1744 | 878 | 4,3 |
| 5 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,065 | 3,0 | 3,9 | 6,2 | 2,7 | s | 2 | 0,0399 | 0,0328 | 0,0159 | 0,0626 | 1100 | 1213 | 1744 | 878 | 4,3 |
| 5 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,065 | 3,0 | 3,9 | 6,2 | 2,7 | s | 3 | 0,0399 | 0,0328 | 0,0159 | 0,0626 | 1100 | 1213 | 1744 | 878 | 4,3 |
| 5 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38,5 | 0,065 | 3,0 | 3,9 | 6,2 | 2,7 | s | 4 | 0,0399 | 0,0328 | 0,0159 | 0,0626 | 1100 | 1213 | 1744 | 878 | 4,3 |
| 6 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,040 | 5,7 | 3,9 | 7,8 | 1,0 | n | 5 | 0,1101 | 0,0541 | 0,0706 | 0,0660 | 245 | 350 | 306 | 317 | 4,2 |
| 6 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,040 | 5,7 | 3,9 | 7,8 | 1,0 | n | 6 | 0,1101 | 0,0541 | 0,0706 | 0,0660 | 245 | 350 | 306 | 317 | 4,2 |
| 6 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,040 | 5,7 | 3,9 | 7,8 | 1,0 | n | 7 | 0,1101 | 0,0541 | 0,0706 | 0,0660 | 245 | 350 | 306 | 317 | 4,2 |
| 6 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,040 | 5,7 | 3,9 | 7,8 | 1,0 | n | 8 | 0,1101 | 0,0541 | 0,0706 | 0,0660 | 245 | 350 | 306 | 317 | 4,2 |
| 7 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,050 | 2,6 | 3,0 | 2,8 | 1,2 | n | 5 | 0,1194 | 0,0911 | 0,1067 | 0,1116 | 283 | 324 | 299 | 292 | 4,2 |
| 7 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,050 | 2,6 | 3,0 | 2,8 | 1,2 | n | 6 | 0,1194 | 0,0911 | 0,1067 | 0,1116 | 283 | 324 | 299 | 292 | 4,2 |
| 7 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,050 | 2,6 | 3,0 | 2,8 | 1,2 | s | 7 | 0,1194 | 0,0911 | 0,1067 | 0,1116 | 283 | 324 | 299 | 292 | 4,2 |
| 7 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,050 | 2,6 | 3,0 | 2,8 | 1,2 | n | 8 | 0,1194 | 0,0911 | 0,1067 | 0,1116 | 283 | 324 | 299 | 292 | 4,2 |
| 8 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,055 | 4,0 | 4,5 | 4,4 | 1,2 | n | 5 | 0,1445 | 0,1022 | 0,1262 | 0,1282 | 257 | 305 | 275 | 273 | 4,2 |
| 8 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,055 | 4,0 | 4,5 | 4,4 | 1,2 | n | 6 | 0,1445 | 0,1022 | 0,1262 | 0,1282 | 257 | 305 | 275 | 273 | 4,2 |
| 8 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,055 | 4,0 | 4,5 | 4,4 | 1,2 | s | 7 | 0,1445 | 0,1022 | 0,1262 | 0,1282 | 257 | 305 | 275 | 273 | 4,2 |
| 8 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,055 | 4,0 | 4,5 | 4,4 | 1,2 | n | 8 | 0,1445 | 0,1022 | 0,1262 | 0,1282 | 257 | 305 | 275 | 273 | 4,2 |
| 9 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,060 | 4,4 | 4,9 | 4,8 | 1,2 | s | 5 | 0,1720 | 0,1194 | 0,1514 | 0,1398 | 235 | 283 | 251 | 261 | 4,2 |
| 9 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,060 | 4,4 | 4,9 | 4,8 | 1,2 | s | 6 | 0,1720 | 0,1194 | 0,1514 | 0,1398 | 235 | 283 | 251 | 261 | 4,2 |
| 9 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,060 | 4,4 | 4,9 | 4,8 | 1,2 | s | 7 | 0,1720 | 0,1194 | 0,1514 | 0,1398 | 235 | 283 | 251 | 261 | 4,2 |
| 9 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,060 | 4,4 | 4,9 | 4,8 | 1,2 | n | 8 | 0,1720 | 0,1194 | 0,1514 | 0,1398 | 235 | 283 | 251 | 261 | 4,2 |
| 10 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,065 | 4,6 | 5,4 | 4,9 | 1,2 | s | 5 | 0,2018 | 0,1416 | 0,1657 | 0,1590 | 217 | 259 | 240 | 245 | 4,2 |
| 10 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,065 | 4,6 | 5,4 | 4,9 | 1,2 | s | 6 | 0,2018 | 0,1416 | 0,1657 | 0,1590 | 217 | 259 | 240 | 245 | 4,2 |
| 10 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,065 | 4,6 | 5,4 | 4,9 | 1,2 | s | 7 | 0,2018 | 0,1416 | 0,1657 | 0,1590 | 217 | 259 | 240 | 245 | 4,2 |
| 10 | 09/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,065 | 4,6 | 5,4 | 4,9 | 1,2 | n | 8 | 0,2018 | 0,1416 | 0,1657 | 0,1590 | 217 | 259 | 240 | 245 | 4,2 |
| 11 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,070 | 5,2 | 5,7 | 5,1 | 1,2 | s | 5 | 0,2341 | 0,1510 | 0,1858 | 0,1722 | 202 | 251 | 226 | 235 | 4,2 |
| 11 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,070 | 5,2 | 5,7 | 5,1 | 1,2 | s | 6 | 0,2341 | 0,1510 | 0,1858 | 0,1722 | 202 | 251 | 226 | 235 | 4,2 |
| 11 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,070 | 5,2 | 5,7 | 5,1 | 1,2 | s | 7 | 0,2341 | 0,1510 | 0,1858 | 0,1722 | 202 | 251 | 226 | 235 | 4,2 |
| 11 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,070 | 5,2 | 5,7 | 5,1 | 1,2 | n | 8 | 0,2341 | 0,1510 | 0,1858 | 0,1722 | 202 | 251 | 226 | 235 | 4,2 |
| 12 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,070 | 5,3 | 6,0 | 5,6 | 1,3 | s | 5 | 0,1994 | 0,1850 | 0,1693 | 0,1881 | 237 | 246 | 257 | 244 | 4,2 |
| 12 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,070 | 5,3 | 6,0 | 5,6 | 1,3 | s | 6 | 0,1994 | 0,1850 | 0,1693 | 0,1881 | 237 | 246 | 257 | 244 | 4,2 |
| 12 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,070 | 5,3 | 6,0 | 5,6 | 1,3 | s | 7 | 0,1994 | 0,1850 | 0,1693 | 0,1881 | 237 | 246 | 257 | 244 | 4,2 |
| 12 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,070 | 5,3 | 6,0 | 5,6 | 1,3 | n | 8 | 0,1994 | 0,1850 | 0,1693 | 0,1881 | 237 | 246 | 257 | 244 | 4,2 |
| 13 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,075 | 6,5 | 6,1 | 6,1 | 1,3 | s | 5 | 0,2289 | 0,2158 | 0,2003 | 0,1976 | 221 | 228 | 236 | 238 | 4,2 |
| 13 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,075 | 6,5 | 6,1 | 6,1 | 1,3 | s | 6 | 0,2289 | 0,2158 | 0,2003 | 0,1976 | 221 | 228 | 236 | 238 | 4,2 |
| 13 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,075 | 6,5 | 6,1 | 6,1 | 1,3 | s | 7 | 0,2289 | 0,2158 | 0,2003 | 0,1976 | 221 | 228 | 236 | 238 | 4,2 |
| 13 | 10/03/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,38 | 1,39 | 0,0507 | 38 | 0,075 | 6,5 | 6,1 | 6,1 | 1,3 | s | 8 | 0,2289 | 0,2158 | 0,2003 | 0,1976 | 221 | 228 | 236 | 238 | 4,2 |

| CASE 5 | | STONES | | | SEDIMENT | | | | FLOW PROPERTIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test number | date | D [cm] | Number of layers | Material | Material | d [cm] | $s=\rho_s/\rho$ | d/D | Water depth [cm] | Hin [m] | $H_{g1}$ [cm] | $H_0$ [cm] | $H_{mes}$ [cm] | T [s] | Suction? Yes=s NO=n | hole number of the section | $\psi_{in}$ | $\psi_{g1}$ | $\psi_0$ | $\psi_{mes}$ | $A_{in}$ | $A_{g1}$ | $A_0$ | $A_{mes}$ | L to breaking [m] |
| | 19/3/2009 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 19/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,030 | 3,1 | 3,4 | 3,2 | 1,0 | n | 1 | 0,0185 | 0,0196 | 0,0240 | 0,0215 | 327 | 318 | 287 | 303 | 4,4 |
| 1 | 19/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,030 | 3,1 | 3,4 | 3,2 | 1,0 | n | 2 | 0,0185 | 0,0196 | 0,0240 | 0,0215 | 327 | 318 | 287 | 303 | 4,4 |
| 1 | 19/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,030 | 3,1 | 3,4 | 3,2 | 1,0 | n | 3 | 0,0185 | 0,0196 | 0,0240 | 0,0215 | 327 | 318 | 287 | 303 | 4,4 |
| 1 | 19/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,030 | 3,1 | 3,4 | 3,2 | 1,0 | n | 4 | 0,0185 | 0,0196 | 0,0240 | 0,0215 | 327 | 318 | 287 | 303 | 4,4 |

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,040 | 3,3 | 3,7 | 4,5 | 1,0 | n | 1 | 0,0329 | 0,0228 | 0,0282 | 0,0415 | 245 | 295 | 265 | 218 | 4,4 |
| 2 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,040 | 3,3 | 3,7 | 4,5 | 1,0 | n | 2 | 0,0329 | 0,0228 | 0,0282 | 0,0415 | 245 | 295 | 265 | 218 | 4,4 |
| 2 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,040 | 3,3 | 3,7 | 4,5 | 1,0 | n | 3 | 0,0329 | 0,0228 | 0,0282 | 0,0415 | 245 | 295 | 265 | 218 | 4,4 |
| 2 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,040 | 3,3 | 3,7 | 4,5 | 1,0 | n | 4 | 0,0329 | 0,0228 | 0,0282 | 0,0415 | 245 | 295 | 265 | 218 | 4,4 |
| 3 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,050 | 4,8 | 5,2 | 5,3 | 1,1 | n | 1 | 0,0425 | 0,0391 | 0,0456 | 0,0483 | 237 | 248 | 229 | 223 | 4,4 |
| 3 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,050 | 4,8 | 5,2 | 5,3 | 1,1 | n | 2 | 0,0425 | 0,0391 | 0,0456 | 0,0483 | 237 | 248 | 229 | 223 | 4,4 |
| 3 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,050 | 4,8 | 5,2 | 5,3 | 1,1 | n | 3 | 0,0425 | 0,0391 | 0,0456 | 0,0483 | 237 | 248 | 229 | 223 | 4,4 |
| 3 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37,5 | 0,050 | 4,8 | 5,2 | 5,3 | 1,1 | n | 4 | 0,0425 | 0,0391 | 0,0456 | 0,0483 | 237 | 248 | 229 | 223 | 4,4 |
| 4 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,060 | 5,4 | 5,9 | 6,0 | 1,1 | n | 1 | 0,0613 | 0,0494 | 0,0584 | 0,0616 | 198 | 220 | 203 | 197 | 4,4 |
| 4 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,060 | 5,4 | 5,9 | 6,0 | 1,1 | n | 2 | 0,0613 | 0,0494 | 0,0584 | 0,0616 | 198 | 220 | 203 | 197 | 4,4 |
| 4 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,060 | 5,4 | 5,9 | 6,0 | 1,1 | n | 3 | 0,0613 | 0,0494 | 0,0584 | 0,0616 | 198 | 220 | 203 | 197 | 4,4 |
| 4 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,060 | 5,4 | 5,9 | 6,0 | 1,1 | n | 4 | 0,0613 | 0,0494 | 0,0584 | 0,0616 | 198 | 220 | 203 | 197 | 4,4 |
| 5 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,070 | 5,7 | 6,2 | 6,3 | 1,2 | n | 1 | 0,0701 | 0,0459 | 0,0551 | 0,0572 | 202 | 249 | 227 | 223 | 4,4 |
| 5 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,070 | 5,7 | 6,2 | 6,3 | 1,2 | n | 2 | 0,0701 | 0,0459 | 0,0551 | 0,0572 | 202 | 249 | 227 | 223 | 4,4 |
| 5 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,070 | 5,7 | 6,2 | 6,3 | 1,2 | n | 3 | 0,0701 | 0,0459 | 0,0551 | 0,0572 | 202 | 249 | 227 | 223 | 4,4 |
| 5 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,070 | 5,7 | 6,2 | 6,3 | 1,2 | n | 4 | 0,0701 | 0,0459 | 0,0551 | 0,0572 | 202 | 249 | 227 | 223 | 4,4 |
| 6 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,075 | 7,4 | 6,9 | 6,4 | 1,2 | n | 1 | 0,0804 | 0,0789 | 0,0687 | 0,0582 | 188 | 190 | 204 | 221 | 4,4 |
| 6 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,075 | 7,4 | 6,9 | 6,4 | 1,2 | n | 2 | 0,0804 | 0,0789 | 0,0687 | 0,0582 | 188 | 190 | 204 | 221 | 4,4 |
| 6 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,075 | 7,4 | 6,9 | 6,4 | 1,2 | n | 3 | 0,0804 | 0,0789 | 0,0687 | 0,0582 | 188 | 190 | 204 | 221 | 4,4 |
| 6 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,075 | 7,4 | 6,9 | 6,4 | 1,2 | n | 4 | 0,0804 | 0,0789 | 0,0687 | 0,0582 | 188 | 190 | 204 | 221 | 4,4 |
| 7 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,085 | 8,0 | 7,6 | 7,0 | 1,3 | n | 1 | 0,0880 | 0,0781 | 0,0699 | 0,0592 | 195 | 207 | 219 | 238 | 4,4 |
| 7 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,085 | 8,0 | 7,6 | 7,0 | 1,3 | s | 2 | 0,0880 | 0,0781 | 0,0699 | 0,0592 | 195 | 207 | 219 | 238 | 4,4 |
| 7 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,085 | 8,0 | 7,6 | 7,0 | 1,3 | s | 3 | 0,0880 | 0,0781 | 0,0699 | 0,0592 | 195 | 207 | 219 | 238 | 4,4 |
| 7 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,085 | 8,0 | 7,6 | 7,0 | 1,3 | n | 4 | 0,0880 | 0,0781 | 0,0699 | 0,0592 | 195 | 207 | 219 | 238 | 4,4 |
| 8 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 4,0 | 3,0 | 4,8 | 1,3 | s | 1 | 0,0987 | 0,0197 | 0,0109 | 0,0285 | 184 | 412 | 554 | 343 | 4,4 |
| 8 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 4,0 | 3,0 | 4,8 | 1,3 | s | 2 | 0,0987 | 0,0197 | 0,0109 | 0,0285 | 184 | 412 | 554 | 343 | 4,4 |
| 8 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 4,0 | 3,0 | 4,8 | 1,3 | s | 3 | 0,0987 | 0,0197 | 0,0109 | 0,0285 | 184 | 412 | 554 | 343 | 4,4 |
| 8 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 4,0 | 3,0 | 4,8 | 1,3 | s | 4 | 0,0987 | 0,0197 | 0,0109 | 0,0285 | 184 | 412 | 554 | 343 | 4,4 |
| 9 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,040 | 6,0 | 3,7 | 6,1 | 3,0 | n | 5 | 0,0037 | 0,0081 | 0,0032 | 0,0086 | 2207 | 1482 | 2376 | 1443 | 4,4 |
| 9 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,040 | 6,0 | 3,7 | 6,1 | 3,0 | n | 6 | 0,0037 | 0,0081 | 0,0032 | 0,0086 | 2207 | 1482 | 2376 | 1443 | 4,4 |
| 9 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,040 | 6,0 | 3,7 | 6,1 | 3,0 | n | 7 | 0,0037 | 0,0081 | 0,0032 | 0,0086 | 2207 | 1482 | 2376 | 1443 | 4,4 |
| 9 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,040 | 6,0 | 3,7 | 6,1 | 3,0 | n | 8 | 0,0037 | 0,0081 | 0,0032 | 0,0086 | 2207 | 1482 | 2376 | 1443 | 4,4 |
| 10 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,050 | 6,3 | 5,0 | 7,7 | 3,1 | n | 5 | 0,0054 | 0,0086 | 0,0053 | 0,0127 | 1885 | 1489 | 1894 | 1224 | 4,4 |
| 10 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,050 | 6,3 | 5,0 | 7,7 | 3,1 | n | 6 | 0,0054 | 0,0086 | 0,0053 | 0,0127 | 1885 | 1489 | 1894 | 1224 | 4,4 |
| 10 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,050 | 6,3 | 5,0 | 7,7 | 3,1 | n | 7 | 0,0054 | 0,0086 | 0,0053 | 0,0127 | 1885 | 1489 | 1894 | 1224 | 4,4 |
| 10 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,050 | 6,3 | 5,0 | 7,7 | 3,1 | n | 8 | 0,0054 | 0,0086 | 0,0053 | 0,0127 | 1885 | 1489 | 1894 | 1224 | 4,4 |
| 11 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,060 | 4,5 | 6,5 | 7,6 | 3,1 | n | 5 | 0,0077 | 0,0043 | 0,0090 | 0,0122 | 1571 | 2111 | 1452 | 1249 | 4,4 |
| 11 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,060 | 4,5 | 6,5 | 7,6 | 3,1 | n | 6 | 0,0077 | 0,0043 | 0,0090 | 0,0122 | 1571 | 2111 | 1452 | 1249 | 4,4 |
| 11 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,060 | 4,5 | 6,5 | 7,6 | 3,1 | n | 7 | 0,0077 | 0,0043 | 0,0090 | 0,0122 | 1571 | 2111 | 1452 | 1249 | 4,4 |
| 11 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,060 | 4,5 | 6,5 | 7,6 | 3,1 | n | 8 | 0,0077 | 0,0043 | 0,0090 | 0,0122 | 1571 | 2111 | 1452 | 1249 | 4,4 |
| 12 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,070 | 5,5 | 7,4 | 8,4 | 3,2 | n | 5 | 0,0099 | 0,0061 | 0,0109 | 0,0141 | 1435 | 1817 | 1363 | 1201 | 4,3 |
| 12 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,070 | 5,5 | 7,4 | 8,4 | 3,2 | n | 6 | 0,0099 | 0,0061 | 0,0109 | 0,0141 | 1435 | 1817 | 1363 | 1201 | 4,3 |
| 12 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,070 | 5,5 | 7,4 | 8,4 | 3,2 | n | 7 | 0,0099 | 0,0061 | 0,0109 | 0,0141 | 1435 | 1817 | 1363 | 1201 | 4,3 |
| 12 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 37 | 0,070 | 5,5 | 7,4 | 8,4 | 3,2 | n | 8 | 0,0099 | 0,0061 | 0,0109 | 0,0141 | 1435 | 1817 | 1363 | 1201 | 4,3 |
| 13 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,080 | 6,2 | 8,2 | 9,1 | 3,2 | n | 5 | 0,0129 | 0,0078 | 0,0135 | 0,0165 | 1256 | 1610 | 1224 | 1109 | 4,4 |
| 13 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,080 | 6,2 | 8,2 | 9,1 | 3,2 | n | 6 | 0,0129 | 0,0078 | 0,0135 | 0,0165 | 1256 | 1610 | 1224 | 1109 | 4,4 |
| 13 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,080 | 6,2 | 8,2 | 9,1 | 3,2 | n | 7 | 0,0129 | 0,0078 | 0,0135 | 0,0165 | 1256 | 1610 | 1224 | 1109 | 4,4 |
| 13 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 38 | 0,080 | 6,2 | 8,2 | 9,1 | 3,2 | n | 8 | 0,0129 | 0,0078 | 0,0135 | 0,0165 | 1256 | 1610 | 1224 | 1109 | 4,4 |
| 14 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 7,6 | 8,8 | 9,2 | 3,4 | n | 5 | 0,0144 | 0,0103 | 0,0138 | 0,0151 | 1260 | 1488 | 1289 | 1234 | 4,4 |
| 14 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 7,6 | 8,8 | 9,2 | 3,4 | n | 6 | 0,0144 | 0,0103 | 0,0138 | 0,0151 | 1260 | 1488 | 1289 | 1234 | 4,4 |
| 14 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 7,6 | 8,8 | 9,2 | 3,4 | n | 7 | 0,0144 | 0,0138 | 0,0138 | 0,0151 | 1260 | 1289 | 1289 | 1234 | 4,4 |
| 14 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 7,6 | 8,8 | 9,2 | 3,4 | s | 8 | 0,0144 | 0,0103 | 0,0138 | 0,0151 | 1260 | 1488 | 1289 | 1234 | 4,4 |
| 15 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,100 | 6,4 | 7,3 | 6,7 | 3,4 | s | 5 | 0,0178 | 0,0072 | 0,0095 | 0,0079 | 1134 | 1780 | 1552 | 1702 | 4,4 |
| 15 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,100 | 6,4 | 7,3 | 6,7 | 3,4 | s | 6 | 0,0178 | 0,0072 | 0,0095 | 0,0079 | 1134 | 1780 | 1552 | 1702 | 4,4 |
| 15 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,100 | 6,4 | 7,3 | 6,7 | 3,4 | s | 7 | 0,0178 | 0,0072 | 0,0095 | 0,0079 | 1134 | 1780 | 1552 | 1702 | 4,4 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,100 | 6,4 | 7,3 | 6,7 | 3,4 | s | 8 | 0,0178 | 0,0072 | 0,0095 | 0,0079 | 1134 | 1780 | 1552 | 1702 | 4,4 |
| 16 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 35 | 0,070 | 7,0 | 7,6 | 5,9 | 5,0 | n | 9 | 0,0040 | 0,0041 | 0,0047 | 0,0029 | 3504 | 3486 | 3235 | 4136 | 4,08 |
| 16 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 35 | 0,070 | 7,0 | 7,6 | 5,9 | 5,0 | n | 10 | 0,0040 | 0,0041 | 0,0047 | 0,0029 | 3504 | 3486 | 3235 | 4136 | 4,08 |
| 16 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 35 | 0,070 | 7,0 | 7,6 | 5,9 | 5,0 | n | 11 | 0,0040 | 0,0041 | 0,0047 | 0,0029 | 3504 | 3486 | 3235 | 4136 | 4,08 |
| 16 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 35 | 0,070 | 7,0 | 7,6 | 5,9 | 5,0 | n | 12 | 0,0040 | 0,0041 | 0,0047 | 0,0029 | 3504 | 3486 | 3235 | 4136 | 4,08 |
| 17 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 35 | 0,080 | 8,1 | 6,9 | 5,8 | 5,0 | s | 9 | 0,0053 | 0,0054 | 0,0039 | 0,0028 | 3066 | 3024 | 3569 | 4219 | 4,08 |
| 17 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 35 | 0,080 | 8,1 | 6,9 | 5,8 | 5,0 | s | 10 | 0,0053 | 0,0054 | 0,0039 | 0,0028 | 3066 | 3024 | 3569 | 4219 | 4,08 |
| 17 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 35 | 0,080 | 8,1 | 6,9 | 5,8 | 5,0 | n | 11 | 0,0053 | 0,0054 | 0,0039 | 0,0028 | 3066 | 3024 | 3569 | 4219 | 4,08 |
| 17 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 35 | 0,080 | 8,1 | 6,9 | 5,8 | 5,0 | n | 12 | 0,0053 | 0,0054 | 0,0039 | 0,0028 | 3066 | 3024 | 3569 | 4219 | 4,08 |
| 18 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 9,0 | 6,3 | 5,4 | 5,2 | s | 9 | 0,0062 | 0,0062 | 0,0030 | 0,0023 | 2947 | 2950 | 4197 | 4871 | 4,4 |
| 18 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 9,0 | 6,3 | 5,4 | 5,2 | s | 10 | 0,0062 | 0,0062 | 0,0030 | 0,0023 | 2947 | 2950 | 4197 | 4871 | 4,4 |
| 18 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 9,0 | 6,3 | 5,4 | 5,2 | n | 11 | 0,0062 | 0,0030 | 0,0030 | 0,0023 | 2947 | 4197 | 4197 | 4871 | 4,4 |
| 18 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,090 | 9,0 | 6,3 | 5,4 | 5,2 | n | 12 | 0,0062 | 0,0062 | 0,0030 | 0,0023 | 2947 | 2950 | 4197 | 4871 | 4,4 |
| 19 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,100 | 9,0 | 6,3 | 5,4 | 5,2 | s | 9 | 0,0076 | 0,0062 | 0,0030 | 0,0023 | 2653 | 2950 | 4197 | 4871 | 4,4 |
| 19 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,100 | 9,0 | 6,3 | 5,4 | 5,2 | s | 10 | 0,0076 | 0,0062 | 0,0030 | 0,0023 | 2653 | 2950 | 4197 | 4871 | 4,4 |
| 19 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,100 | 9,0 | 6,3 | 5,4 | 5,2 | s | 11 | 0,0076 | 0,0062 | 0,0030 | 0,0023 | 2653 | 2950 | 4197 | 4871 | 4,4 |
| 19 | 20/3/2009 | 4 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,075 | 39 | 0,100 | 9,0 | 6,3 | 5,4 | 5,2 | s | 12 | 0,0076 | 0,0062 | 0,0030 | 0,0023 | 2653 | 2950 | 4197 | 4871 | 4,4 |

| CASE 6 | | STONES | | | SEDIMENT | | | | FLOW PROPERTIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test number | date | D [cm] | Number of layers | Material | Material | d [cm] | $s=\rho_s/\rho$ | d/D | Water depth [cm] | Hin [m] | $H_{g1}$ [cm] | $H_0$ [cm] | $H_{mes}$ [cm] | T [s] | Suction? Yes=s NO=n | hole number of the section | $\psi_{in}$ | $\psi_{g1}$ | $\psi_0$ | $\psi_{mes}$ | $A_{in}$ | $A_{g1}$ | $A_0$ | $A_{mes}$ | L to breaking [m] |
| 1 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,030 | 3,2 | 4,7 | 2,4 | 4,8 | n | 1 | 0,0017 | 0,0019 | 0,0043 | 0,0011 | 7534 | 7143 | 4792 | 9357 | 4,32 |
| 1 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,030 | 3,2 | 4,7 | 2,4 | 4,8 | n | 2 | 0,0017 | 0,0019 | 0,0043 | 0,0011 | 7534 | 7143 | 4792 | 9357 | 4,32 |
| 1 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,030 | 3,2 | 4,7 | 2,4 | 4,8 | n | 3 | 0,0017 | 0,0019 | 0,0043 | 0,0011 | 7534 | 7143 | 4792 | 9357 | 4,32 |
| 1 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,030 | 3,2 | 4,7 | 2,4 | 4,8 | n | 4 | 0,0017 | 0,0019 | 0,0043 | 0,0011 | 7534 | 7143 | 4792 | 9357 | 4,32 |
| 2 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,035 | 2,4 | 4,1 | 2,2 | 4,8 | n | 1 | 0,0023 | 0,0011 | 0,0032 | 0,0009 | 6458 | 9337 | 5572 | 10380 | 4,32 |
| 2 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,035 | 2,4 | 4,1 | 2,2 | 4,8 | s | 2 | 0,0023 | 0,0011 | 0,0032 | 0,0009 | 6458 | 9337 | 5572 | 10380 | 4,32 |
| 2 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,035 | 2,4 | 4,1 | 2,2 | 4,8 | s | 3 | 0,0023 | 0,0011 | 0,0032 | 0,0009 | 6458 | 9337 | 5572 | 10380 | 4,32 |
| 2 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,035 | 2,4 | 4,1 | 2,2 | 4,8 | n | 4 | 0,0023 | 0,0011 | 0,0032 | 0,0009 | 6458 | 9337 | 5572 | 10380 | 4,32 |
| 3 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,040 | 2,8 | 3,8 | 3,7 | 5,0 | n | 1 | 0,0028 | 0,0014 | 0,0026 | 0,0025 | 6131 | 8651 | 6393 | 6580 | 4,32 |
| 3 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,040 | 2,8 | 3,8 | 3,7 | 5,0 | n | 2 | 0,0028 | 0,0014 | 0,0026 | 0,0025 | 6131 | 8651 | 6393 | 6580 | 4,32 |
| 3 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,040 | 2,8 | 3,8 | 3,7 | 5,0 | n | 3 | 0,0028 | 0,0014 | 0,0026 | 0,0025 | 6131 | 8651 | 6393 | 6580 | 4,32 |
| 3 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,040 | 2,8 | 3,8 | 3,7 | 5,0 | n | 4 | 0,0028 | 0,0014 | 0,0026 | 0,0025 | 6131 | 8651 | 6393 | 6580 | 4,32 |
| 4 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,050 | 4,1 | 3,4 | 4,2 | 5,2 | s | 1 | 0,0041 | 0,0028 | 0,0019 | 0,0029 | 5305 | 6414 | 7820 | 6261 | 4,32 |
| 4 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,050 | 4,1 | 3,4 | 4,2 | 5,2 | s | 2 | 0,0041 | 0,0028 | 0,0019 | 0,0029 | 5305 | 6414 | 7820 | 6261 | 4,32 |
| 4 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,050 | 4,1 | 3,4 | 4,2 | 5,2 | s | 3 | 0,0041 | 0,0028 | 0,0019 | 0,0029 | 5305 | 6414 | 7820 | 6261 | 4,32 |
| 4 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,050 | 4,1 | 3,4 | 4,2 | 5,2 | n | 4 | 0,0041 | 0,0028 | 0,0019 | 0,0029 | 5305 | 6414 | 7820 | 6261 | 4,32 |
| 5 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,060 | 5,4 | 3,3 | 5,4 | 5,3 | s | 1 | 0,0057 | 0,0045 | 0,0018 | 0,0046 | 4593 | 5122 | 8232 | 5116 | 4,32 |
| 5 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,060 | 5,4 | 3,3 | 5,4 | 5,3 | s | 2 | 0,0057 | 0,0045 | 0,0018 | 0,0046 | 4593 | 5122 | 8232 | 5116 | 4,32 |
| 5 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,060 | 5,4 | 3,3 | 5,4 | 5,3 | s | 3 | 0,0057 | 0,0045 | 0,0018 | 0,0046 | 4593 | 5122 | 8232 | 5116 | 4,32 |
| 5 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37,5 | 0,060 | 5,4 | 3,3 | 5,4 | 5,3 | s | 4 | 0,0057 | 0,0045 | 0,0018 | 0,0046 | 4593 | 5122 | 8232 | 5116 | 4,32 |
| 6 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,030 | 3,7 | 2,0 | 3,2 | 3,0 | n | 1 | 0,0044 | 0,0069 | 0,0020 | 0,0049 | 2943 | 2361 | 4368 | 2787 | 4,28 |
| 6 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,030 | 3,7 | 2,0 | 3,2 | 3,0 | n | 2 | 0,0044 | 0,0069 | 0,0020 | 0,0049 | 2943 | 2361 | 4368 | 2787 | 4,28 |
| 6 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,030 | 3,7 | 2,0 | 3,2 | 3,0 | n | 3 | 0,0044 | 0,0069 | 0,0020 | 0,0049 | 2943 | 2361 | 4368 | 2787 | 4,28 |
| 6 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,030 | 3,7 | 2,0 | 3,2 | 3,0 | n | 4 | 0,0044 | 0,0069 | 0,0020 | 0,0049 | 2943 | 2361 | 4368 | 2787 | 4,28 |
| 7 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,040 | 4,5 | 2,9 | 4,6 | 3,0 | s | 1 | 0,0078 | 0,0099 | 0,0040 | 0,0105 | 2207 | 1963 | 3081 | 1910 | 4,28 |
| 7 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,040 | 4,5 | 2,9 | 4,6 | 3,0 | s | 2 | 0,0078 | 0,0099 | 0,0040 | 0,0105 | 2207 | 1963 | 3081 | 1910 | 4,28 |
| 7 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,040 | 4,5 | 2,9 | 4,6 | 3,0 | n | 3 | 0,0078 | 0,0099 | 0,0040 | 0,0105 | 2207 | 1963 | 3081 | 1910 | 4,28 |
| 7 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,040 | 4,5 | 2,9 | 4,6 | 3,0 | n | 4 | 0,0078 | 0,0099 | 0,0040 | 0,0105 | 2207 | 1963 | 3081 | 1910 | 4,28 |
| 8 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,050 | 5,2 | 3,8 | 5,8 | 3,0 | s | 1 | 0,0123 | 0,0132 | 0,0071 | 0,0168 | 1766 | 1702 | 2323 | 1510 | 4,28 |
| 8 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,050 | 5,2 | 3,8 | 5,8 | 3,0 | s | 2 | 0,0123 | 0,0132 | 0,0071 | 0,0168 | 1766 | 1702 | 2323 | 1510 | 4,28 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,050 | 5,2 | 3,8 | 5,8 | 3,0 | s | 3 | 0,0123 | 0,0132 | 0,0071 | 0,0168 | 1766 | 1702 | 2323 | 1510 | 4,28 |
| 8 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,050 | 5,2 | 3,8 | 5,8 | 3,0 | s | 4 | 0,0123 | 0,0132 | 0,0071 | 0,0168 | 1766 | 1702 | 2323 | 1510 | 4,28 |
| 9 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,035 | 2,5 | 2,8 | 2,8 | 1,0 | n | 1 | 0,0541 | 0,0279 | 0,0357 | 0,0338 | 280 | 390 | 345 | 355 | 4,1 |
| 9 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,035 | 2,5 | 2,8 | 2,8 | 1,0 | n | 2 | 0,0541 | 0,0279 | 0,0357 | 0,0338 | 280 | 390 | 345 | 355 | 4,1 |
| 9 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,035 | 2,5 | 2,8 | 2,8 | 1,0 | n | 3 | 0,0541 | 0,0279 | 0,0357 | 0,0338 | 280 | 390 | 345 | 355 | 4,1 |
| 9 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,035 | 2,5 | 2,8 | 2,8 | 1,0 | n | 4 | 0,0541 | 0,0279 | 0,0357 | 0,0338 | 280 | 390 | 345 | 355 | 4,1 |
| 10 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,040 | 2,8 | 3,2 | 3,2 | 1,0 | n | 1 | 0,0706 | 0,0343 | 0,0464 | 0,0445 | 245 | 352 | 303 | 309 | 4,1 |
| 10 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,040 | 2,8 | 3,2 | 3,2 | 1,0 | n | 2 | 0,0706 | 0,0343 | 0,0464 | 0,0445 | 245 | 352 | 303 | 309 | 4,1 |
| 10 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,040 | 2,8 | 3,2 | 3,2 | 1,0 | n | 3 | 0,0706 | 0,0343 | 0,0464 | 0,0445 | 245 | 352 | 303 | 309 | 4,1 |
| 10 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,040 | 2,8 | 3,2 | 3,2 | 1,0 | n | 4 | 0,0706 | 0,0343 | 0,0464 | 0,0445 | 245 | 352 | 303 | 309 | 4,1 |
| 11 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,050 | 3,8 | 3,3 | 4,0 | 1,1 | n | 1 | 0,0912 | 0,0520 | 0,0386 | 0,0570 | 237 | 314 | 365 | 300 | 4,1 |
| 11 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,050 | 3,8 | 3,3 | 4,0 | 1,1 | n | 2 | 0,0912 | 0,0520 | 0,0386 | 0,0570 | 237 | 314 | 365 | 300 | 4,1 |
| 11 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,050 | 3,8 | 3,3 | 4,0 | 1,1 | n | 3 | 0,0912 | 0,0520 | 0,0386 | 0,0570 | 237 | 314 | 365 | 300 | 4,1 |
| 11 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36 | 0,050 | 3,8 | 3,3 | 4,0 | 1,1 | n | 4 | 0,0912 | 0,0520 | 0,0386 | 0,0570 | 237 | 314 | 365 | 300 | 4,1 |
| 12 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,060 | 4,5 | 4,1 | 4,7 | 1,1 | s | 1 | 0,1313 | 0,0749 | 0,0628 | 0,0798 | 198 | 262 | 286 | 254 | 4,1 |
| 12 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,060 | 4,5 | 4,1 | 4,7 | 1,1 | n | 2 | 0,1313 | 0,0749 | 0,0628 | 0,0798 | 198 | 262 | 286 | 254 | 4,1 |
| 12 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,060 | 4,5 | 4,1 | 4,7 | 1,1 | n | 3 | 0,1313 | 0,0749 | 0,0628 | 0,0798 | 198 | 262 | 286 | 254 | 4,1 |
| 12 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,060 | 4,5 | 4,1 | 4,7 | 1,1 | n | 4 | 0,1313 | 0,0749 | 0,0628 | 0,0798 | 198 | 262 | 286 | 254 | 4,1 |
| 13 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,070 | 5,1 | 4,9 | 5,6 | 1,1 | s | 1 | 0,1787 | 0,0932 | 0,0881 | 0,1128 | 170 | 235 | 241 | 213 | 4,1 |
| 13 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,070 | 5,1 | 4,9 | 5,6 | 1,1 | n | 2 | 0,1787 | 0,0932 | 0,0881 | 0,1128 | 170 | 235 | 241 | 213 | 4,1 |
| 13 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,070 | 5,1 | 4,9 | 5,6 | 1,1 | n | 3 | 0,1787 | 0,0932 | 0,0881 | 0,1128 | 170 | 235 | 241 | 213 | 4,1 |
| 13 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,070 | 5,1 | 4,9 | 5,6 | 1,1 | n | 4 | 0,1787 | 0,0932 | 0,0881 | 0,1128 | 170 | 235 | 241 | 213 | 4,1 |
| 14 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,080 | 5,6 | 5,6 | 6,3 | 1,1 | s | 1 | 0,2334 | 0,1144 | 0,1124 | 0,1435 | 148 | 212 | 214 | 189 | 4,1 |
| 14 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,080 | 5,6 | 5,6 | 6,3 | 1,1 | n | 2 | 0,2334 | 0,1144 | 0,1124 | 0,1435 | 148 | 212 | 214 | 189 | 4,1 |
| 14 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,080 | 5,6 | 5,6 | 6,3 | 1,1 | s | 3 | 0,2334 | 0,1144 | 0,1124 | 0,1435 | 148 | 212 | 214 | 189 | 4,1 |
| 14 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,080 | 5,6 | 5,6 | 6,3 | 1,1 | s | 4 | 0,2334 | 0,1144 | 0,1124 | 0,1435 | 148 | 212 | 214 | 189 | 4,1 |
| 15 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,090 | 6,9 | 6,7 | 5,9 | 1,1 | s | 1 | 0,2954 | 0,1744 | 0,1617 | 0,1266 | 132 | 172 | 178 | 201 | 4,1 |
| 15 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,090 | 6,9 | 6,7 | 5,9 | 1,1 | n | 2 | 0,2954 | 0,1744 | 0,1617 | 0,1266 | 132 | 172 | 178 | 201 | 4,1 |
| 15 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,090 | 6,9 | 6,7 | 5,9 | 1,1 | s | 3 | 0,2954 | 0,1744 | 0,1617 | 0,1266 | 132 | 172 | 178 | 201 | 4,1 |
| 15 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 36,5 | 0,090 | 6,9 | 6,7 | 5,9 | 1,1 | s | 4 | 0,2954 | 0,1744 | 0,1617 | 0,1266 | 132 | 172 | 178 | 201 | 4,1 |
| 16 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,100 | 7,8 | 7,3 | 6,1 | 1,1 | s | 1 | 0,3647 | 0,2201 | 0,1928 | 0,1373 | 119 | 153 | 163 | 193 | 4,1 |
| 16 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,100 | 7,8 | 7,3 | 6,1 | 1,1 | s | 2 | 0,3647 | 0,2201 | 0,1928 | 0,1373 | 119 | 153 | 163 | 193 | 4,1 |
| 16 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,100 | 7,8 | 7,3 | 6,1 | 1,1 | s | 3 | 0,3647 | 0,2201 | 0,1928 | 0,1373 | 119 | 153 | 163 | 193 | 4,1 |
| 16 | 10/04/2009 | 4 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,035 | 37 | 0,100 | 7,8 | 7,3 | 6,1 | 1,1 | s | 4 | 0,3647 | 0,2201 | 0,1928 | 0,1373 | 119 | 153 | 163 | 193 | 4,1 |

| CASE 7 | | STONES | | | SEDIMENT | | | | FLOW PROPERTIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test number | date | D [cm] | Number of layers | Material | Material | d [cm] | $s=\rho_s/\rho$ | d/D | Water depth [cm] | Hin [m] | $H_{g1}$ [cm] | $H_0$ [cm] | $H_{mes}$ [cm] | T [s] | Suction? Yes=s NO=n | hole number of the section | $\psi_{in}$ | $\psi_{g1}$ | $\psi_0$ | $\psi_{mes}$ | $A_{in}$ | $A_{g1}$ | $A_0$ | $A_{mes}$ | L to breaking [m] |
| | 12/04/2009 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,065 | 6,0 | 5,9 | 6,7 | 5,0 | n | 1 | 0,0075 | 0,0064 | 0,0061 | 0,0078 | 3773 | 4065 | 4185 | 3680 | 4,32 |
| 1 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,065 | 6,0 | 5,9 | 6,7 | 5,0 | n | 2 | 0,0075 | 0,0064 | 0,0061 | 0,0078 | 3773 | 4065 | 4185 | 3680 | 4,32 |
| 1 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,065 | 6,0 | 5,9 | 6,7 | 5,0 | n | 3 | 0,0075 | 0,0064 | 0,0061 | 0,0078 | 3773 | 4065 | 4185 | 3680 | 4,32 |
| 1 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,065 | 6,0 | 5,9 | 6,7 | 5,0 | n | 4 | 0,0075 | 0,0064 | 0,0061 | 0,0078 | 3773 | 4065 | 4185 | 3680 | 4,32 |
| 2 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,075 | 6,5 | 5,7 | 7,3 | 5,1 | n | 1 | 0,0095 | 0,0072 | 0,0055 | 0,0090 | 3402 | 3925 | 4465 | 3502 | 4,32 |
| 2 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,075 | 6,5 | 5,7 | 7,3 | 5,1 | n | 2 | 0,0095 | 0,0072 | 0,0055 | 0,0090 | 3402 | 3925 | 4465 | 3502 | 4,32 |
| 2 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,075 | 6,5 | 5,7 | 7,3 | 5,1 | n | 3 | 0,0095 | 0,0072 | 0,0055 | 0,0090 | 3402 | 3925 | 4465 | 3502 | 4,32 |
| 2 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,075 | 6,5 | 5,7 | 7,3 | 5,1 | n | 4 | 0,0095 | 0,0072 | 0,0055 | 0,0090 | 3402 | 3925 | 4465 | 3502 | 4,32 |
| 3 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 39 | 0,085 | 7,8 | 5,9 | 8,4 | 5,1 | s | 1 | 0,0123 | 0,0102 | 0,0059 | 0,0121 | 3002 | 3288 | 4313 | 3023 | 4,32 |
| 3 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 39 | 0,085 | 7,8 | 5,9 | 8,4 | 5,1 | n | 2 | 0,0123 | 0,0102 | 0,0059 | 0,0121 | 3002 | 3288 | 4313 | 3023 | 4,32 |
| 3 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 39 | 0,085 | 7,8 | 5,9 | 8,4 | 5,1 | n | 3 | 0,0123 | 0,0102 | 0,0059 | 0,0121 | 3002 | 3288 | 4313 | 3023 | 4,32 |
| 3 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 39 | 0,085 | 7,8 | 5,9 | 8,4 | 5,1 | n | 4 | 0,0123 | 0,0102 | 0,0059 | 0,0121 | 3002 | 3288 | 4313 | 3023 | 4,32 |
| 4 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,095 | 8,7 | 7,1 | 9,4 | 5,1 | s | 1 | 0,0153 | 0,0128 | 0,0085 | 0,0151 | 2686 | 2935 | 3602 | 2703 | 4,32 |
| 4 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,095 | 8,7 | 7,1 | 9,4 | 5,1 | s | 2 | 0,0153 | 0,0128 | 0,0085 | 0,0151 | 2686 | 2935 | 3602 | 2703 | 4,32 |
| 4 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,095 | 8,7 | 7,1 | 9,4 | 5,1 | s | 3 | 0,0153 | 0,0128 | 0,0085 | 0,0151 | 2686 | 2935 | 3602 | 2703 | 4,32 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,095 | 8,7 | 7,1 | 9,4 | 5,1 | n | 4 | 0,0153 | 0,0128 | 0,0085 | 0,0151 | 2686 | 2935 | 3602 | 2703 | 4,32 |
| 5 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,105 | 11,0 | 7,0 | 9,1 | 5,2 | s | 1 | 0,0180 | 0,0197 | 0,0079 | 0,0134 | 2526 | 2411 | 3813 | 2928 | 4,32 |
| 5 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,105 | 11,0 | 7,0 | 9,1 | 5,2 | s | 2 | 0,0180 | 0,0197 | 0,0079 | 0,0134 | 2526 | 2411 | 3813 | 2928 | 4,32 |
| 5 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,105 | 11,0 | 7,0 | 9,1 | 5,2 | s | 3 | 0,0180 | 0,0197 | 0,0079 | 0,0134 | 2526 | 2411 | 3813 | 2928 | 4,32 |
| 5 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,105 | 11,0 | 7,0 | 9,1 | 5,2 | s | 4 | 0,0180 | 0,0197 | 0,0079 | 0,0134 | 2526 | 2411 | 3813 | 2928 | 4,32 |
| 6 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 36,5 | 0,065 | 6,7 | 4,4 | 8,4 | 3,0 | n | 1 | 0,0207 | 0,0223 | 0,0096 | 0,0344 | 1358 | 1309 | 1997 | 1054 | 4,12 |
| 6 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 36,5 | 0,065 | 6,7 | 4,4 | 8,4 | 3,0 | n | 2 | 0,0207 | 0,0223 | 0,0096 | 0,0344 | 1358 | 1309 | 1997 | 1054 | 4,12 |
| 6 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 36,5 | 0,065 | 6,7 | 4,4 | 8,4 | 3,0 | n | 3 | 0,0207 | 0,0223 | 0,0096 | 0,0344 | 1358 | 1309 | 1997 | 1054 | 4,12 |
| 6 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 36,5 | 0,065 | 6,7 | 4,4 | 8,4 | 3,0 | n | 4 | 0,0207 | 0,0223 | 0,0096 | 0,0344 | 1358 | 1309 | 1997 | 1054 | 4,12 |
| 7 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,075 | 7,7 | 5,8 | 9,0 | 3,0 | n | 1 | 0,0276 | 0,0293 | 0,0164 | 0,0394 | 1177 | 1142 | 1525 | 985 | 4,12 |
| 7 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,075 | 7,7 | 5,8 | 9,0 | 3,0 | n | 2 | 0,0276 | 0,0293 | 0,0164 | 0,0394 | 1177 | 1142 | 1525 | 985 | 4,12 |
| 7 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,075 | 7,7 | 5,8 | 9,0 | 3,0 | n | 3 | 0,0276 | 0,0293 | 0,0164 | 0,0394 | 1177 | 1142 | 1525 | 985 | 4,12 |
| 7 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,075 | 7,7 | 5,8 | 9,0 | 3,0 | n | 4 | 0,0276 | 0,0293 | 0,0164 | 0,0394 | 1177 | 1142 | 1525 | 985 | 4,12 |
| 8 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,085 | 8,2 | 6,9 | 9,4 | 3,0 | n | 1 | 0,0354 | 0,0328 | 0,0235 | 0,0434 | 1039 | 1079 | 1276 | 938 | 4,12 |
| 8 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,085 | 8,2 | 6,9 | 9,4 | 3,0 | n | 2 | 0,0354 | 0,0328 | 0,0235 | 0,0434 | 1039 | 1079 | 1276 | 938 | 4,12 |
| 8 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,085 | 8,2 | 6,9 | 9,4 | 3,0 | n | 3 | 0,0354 | 0,0328 | 0,0235 | 0,0434 | 1039 | 1079 | 1276 | 938 | 4,12 |
| 8 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,085 | 8,2 | 6,9 | 9,4 | 3,0 | n | 4 | 0,0354 | 0,0328 | 0,0235 | 0,0434 | 1039 | 1079 | 1276 | 938 | 4,12 |
| 9 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,095 | 8,7 | 8,0 | 9,6 | 3,0 | n | 1 | 0,0443 | 0,0375 | 0,0315 | 0,0448 | 929 | 1009 | 1101 | 924 | 4,12 |
| 9 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,095 | 8,7 | 8,0 | 9,6 | 3,0 | n | 2 | 0,0443 | 0,0375 | 0,0315 | 0,0448 | 929 | 1009 | 1101 | 924 | 4,12 |
| 9 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,095 | 8,7 | 8,0 | 9,6 | 3,0 | n | 3 | 0,0443 | 0,0375 | 0,0315 | 0,0448 | 929 | 1009 | 1101 | 924 | 4,12 |
| 9 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 37,5 | 0,095 | 8,7 | 8,0 | 9,6 | 3,0 | n | 4 | 0,0443 | 0,0375 | 0,0315 | 0,0448 | 929 | 1009 | 1101 | 924 | 4,12 |
| 10 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,105 | 9,3 | 10,0 | 9,7 | 3,0 | n | 1 | 0,0541 | 0,0426 | 0,0486 | 0,0466 | 841 | 947 | 887 | 906 | 4,12 |
| 10 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,105 | 9,3 | 10,0 | 9,7 | 3,0 | n | 2 | 0,0541 | 0,0426 | 0,0486 | 0,0466 | 841 | 947 | 887 | 906 | 4,12 |
| 10 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,105 | 9,3 | 10,0 | 9,7 | 3,0 | n | 3 | 0,0541 | 0,0426 | 0,0486 | 0,0466 | 841 | 947 | 887 | 906 | 4,12 |
| 10 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,105 | 9,3 | 10,0 | 9,7 | 3,0 | n | 4 | 0,0541 | 0,0426 | 0,0486 | 0,0466 | 841 | 947 | 887 | 906 | 4,12 |
| 11 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,115 | 10,2 | 10,6 | 9,5 | 3,0 | n | 1 | 0,0648 | 0,0508 | 0,0556 | 0,0439 | 768 | 867 | 829 | 933 | 4,12 |
| 11 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,115 | 10,2 | 10,6 | 9,5 | 3,0 | n | 2 | 0,0648 | 0,0508 | 0,0556 | 0,0439 | 768 | 867 | 829 | 933 | 4,12 |
| 11 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,115 | 10,2 | 10,6 | 9,5 | 3,0 | n | 3 | 0,0648 | 0,0508 | 0,0556 | 0,0439 | 768 | 867 | 829 | 933 | 4,12 |
| 11 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,115 | 10,2 | 10,6 | 9,5 | 3,0 | n | 4 | 0,0648 | 0,0508 | 0,0556 | 0,0439 | 768 | 867 | 829 | 933 | 4,12 |
| 12 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,125 | 10,5 | 11,7 | 8,6 | 3,0 | s | 1 | 0,0766 | 0,0542 | 0,0676 | 0,0363 | 706 | 840 | 752 | 1027 | 4,12 |
| 12 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,125 | 10,5 | 11,7 | 8,6 | 3,0 | n | 2 | 0,0766 | 0,0542 | 0,0676 | 0,0363 | 706 | 840 | 752 | 1027 | 4,12 |
| 12 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,125 | 10,5 | 11,7 | 8,6 | 3,0 | n | 3 | 0,0766 | 0,0542 | 0,0676 | 0,0363 | 706 | 840 | 752 | 1027 | 4,12 |
| 12 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,125 | 10,5 | 11,7 | 8,6 | 3,0 | n | 4 | 0,0766 | 0,0542 | 0,0676 | 0,0363 | 706 | 840 | 752 | 1027 | 4,12 |
| 13 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,135 | 11,2 | 13,2 | 8,5 | 3,0 | s | 1 | 0,0894 | 0,0617 | 0,0849 | 0,0353 | 654 | 787 | 671 | 1041 | 4,12 |
| 13 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,135 | 11,2 | 13,2 | 8,5 | 3,0 | n | 2 | 0,0894 | 0,0617 | 0,0849 | 0,0353 | 654 | 787 | 671 | 1041 | 4,12 |
| 13 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,135 | 11,2 | 13,2 | 8,5 | 3,0 | n | 3 | 0,0894 | 0,0617 | 0,0849 | 0,0353 | 654 | 787 | 671 | 1041 | 4,12 |
| 13 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,135 | 11,2 | 13,2 | 8,5 | 3,0 | n | 4 | 0,0894 | 0,0617 | 0,0849 | 0,0353 | 654 | 787 | 671 | 1041 | 4,12 |
| 14 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 39,5 | 0,145 | 11,6 | 14,8 | 7,9 | 3,0 | s | 1 | 0,1031 | 0,0658 | 0,1070 | 0,0305 | 609 | 762 | 598 | 1120 | 4,12 |
| 14 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 39,5 | 0,145 | 11,6 | 14,8 | 7,9 | 3,0 | s | 2 | 0,1031 | 0,0658 | 0,1070 | 0,0305 | 609 | 762 | 598 | 1120 | 4,12 |
| 14 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 39,5 | 0,145 | 11,6 | 14,8 | 7,9 | 3,0 | n | 3 | 0,1031 | 0,0658 | 0,1070 | 0,0305 | 609 | 762 | 598 | 1120 | 4,12 |
| 14 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 39,5 | 0,145 | 11,6 | 14,8 | 7,9 | 3,0 | s | 4 | 0,1031 | 0,0658 | 0,1070 | 0,0305 | 609 | 762 | 598 | 1120 | 4,12 |
| 13 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40,5 | 0,155 | 11,2 | 13,2 | 8,5 | 3,0 | s | 1 | 0,1178 | 0,0617 | 0,0849 | 0,0353 | 570 | 787 | 671 | 1041 | 4,12 |
| 13 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40,5 | 0,155 | 11,2 | 13,2 | 8,5 | 3,0 | s | 2 | 0,1178 | 0,0617 | 0,0849 | 0,0353 | 570 | 787 | 671 | 1041 | 4,12 |
| 13 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40,5 | 0,155 | 11,2 | 13,2 | 8,5 | 3,0 | s | 3 | 0,1178 | 0,0617 | 0,0849 | 0,0353 | 570 | 787 | 671 | 1041 | 4,12 |
| 13 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40,5 | 0,155 | 11,2 | 13,2 | 8,5 | 3,0 | s | 4 | 0,1178 | 0,0617 | 0,0849 | 0,0353 | 570 | 787 | 671 | 1041 | 4,12 |
| 14 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,120 | 11,6 | 14,8 | 7,9 | 1,0 | n | 1 | 0,6355 | 0,5922 | 0,9628 | 0,2744 | 82 | 85 | 66 | 124 | 4,15 |
| 14 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,120 | 11,6 | 14,8 | 7,9 | 1,0 | n | 2 | 0,6355 | 0,5922 | 0,9628 | 0,2744 | 82 | 85 | 66 | 124 | 4,15 |
| 14 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,120 | 11,6 | 14,8 | 7,9 | 1,0 | n | 3 | 0,6355 | 0,5922 | 0,9628 | 0,2744 | 82 | 85 | 66 | 124 | 4,15 |
| 14 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 38,5 | 0,120 | 11,6 | 14,8 | 7,9 | 1,0 | n | 4 | 0,6355 | 0,5922 | 0,9628 | 0,2744 | 82 | 85 | 66 | 124 | 4,15 |
| 15 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,135 | 12,2 | 15,6 | 7,9 | 1,0 | n | 1 | 0,8042 | 0,6622 | 1,0765 | 0,2768 | 73 | 80 | 63 | 124 | 4,1 |
| 15 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,135 | 12,2 | 15,6 | 7,9 | 1,0 | n | 2 | 0,8042 | 0,6622 | 1,0765 | 0,2768 | 73 | 80 | 63 | 124 | 4,1 |
| 15 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,135 | 12,2 | 15,6 | 7,9 | 1,0 | n | 3 | 0,8042 | 0,6622 | 1,0765 | 0,2768 | 73 | 80 | 63 | 124 | 4,1 |
| 15 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 40 | 0,135 | 12,2 | 15,6 | 7,9 | 1,0 | n | 4 | 0,8042 | 0,6622 | 1,0765 | 0,2768 | 73 | 80 | 63 | 124 | 4,1 |
| 16 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 41 | 0,150 | 8,7 | 10,1 | 7,2 | 1,0 | n | 1 | 0,9929 | 0,3345 | 0,4521 | 0,2257 | 65 | 113 | 97 | 137 | 4,1 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 41 | 0,150 | 8,7 | 10,1 | 7,2 | 1,0 | n | 2 | 0,9929 | 0,3345 | 0,4521 | 0,2257 | 65 | 113 | 97 | 137 | 4,1 |
| 16 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 41 | 0,150 | 8,7 | 10,1 | 7,2 | 1,0 | n | 3 | 0,9929 | 0,3345 | 0,4521 | 0,2257 | 65 | 113 | 97 | 137 | 4,1 |
| 16 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 41 | 0,150 | 8,7 | 10,1 | 7,2 | 1,0 | n | 4 | 0,9929 | 0,3345 | 0,4521 | 0,2257 | 65 | 113 | 97 | 137 | 4,1 |
| 17 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 41 | 0,160 | 10,3 | 11,3 | 8,0 | 1,0 | n | 1 | 1,1297 | 0,4679 | 0,5635 | 0,2800 | 61 | 95 | 87 | 123 | 4,1 |
| 17 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 41 | 0,160 | 10,3 | 11,3 | 8,0 | 1,0 | n | 2 | 1,1297 | 0,4679 | 0,5635 | 0,2800 | 61 | 95 | 87 | 123 | 4,1 |
| 17 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 41 | 0,160 | 10,3 | 11,3 | 8,0 | 1,0 | n | 3 | 1,1297 | 0,4679 | 0,5635 | 0,2800 | 61 | 95 | 87 | 123 | 4,1 |
| 17 | 12/04/2009 | 7,5 | 2x4cm | Natural stones | Particles | 0,14 | 2,65 | 0,0187 | 41 | 0,160 | 10,3 | 11,3 | 8,0 | 1,0 | n | 4 | 1,1297 | 0,4679 | 0,5635 | 0,2800 | 61 | 95 | 87 | 123 | 4,1 |

| CASE 8 | | STONES | | | SEDIMENT | | | | FLOW PROPERTIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test number | date | D [cm] | Number of layers | Material | Material | d [cm] | $s=\rho_s/\rho$ | d/D | Water depth [cm] | Hin [m] | $H_{g1}$ [cm] | $H_0$ [cm] | $H_{mes}$ [cm] | T [s] | Suction? Yes=s NO=n | hole number of the section | $\psi_{in}$ | $\psi_{g1}$ | $\psi_0$ | $\psi_{mes}$ | $A_{in}$ | $A_{g1}$ | $A_0$ | $A_{mes}$ | L to breaking [m] |
| | 11/05/2009 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,035 | 2,8 | 4,4 | 3,5 | 5,0 | s | 1 | 0,0034 | 0,0022 | 0,0052 | 0,0034 | 7007 | 8720 | 5621 | 6967 | 4,34 |
| 1 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,035 | 2,8 | 4,4 | 3,5 | 5,0 | s | 2 | 0,0034 | 0,0022 | 0,0052 | 0,0034 | 7007 | 8720 | 5621 | 6967 | 4,34 |
| 1 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,035 | 2,8 | 4,4 | 3,5 | 5,0 | s | 3 | 0,0034 | 0,0022 | 0,0052 | 0,0034 | 7007 | 8720 | 5621 | 6967 | 4,34 |
| 2 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,035 | 4,7 | 2,9 | 3,7 | 3,0 | s | 1 | 0,0094 | 0,0171 | 0,0062 | 0,0105 | 2523 | 1869 | 3091 | 2382 | 4,34 |
| 2 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,035 | 4,7 | 2,9 | 3,7 | 3,0 | s | 2 | 0,0094 | 0,0171 | 0,0062 | 0,0105 | 2523 | 1869 | 3091 | 2382 | 4,34 |
| 2 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,035 | 4,7 | 2,9 | 3,7 | 3,0 | s | 3 | 0,0094 | 0,0171 | 0,0062 | 0,0105 | 2523 | 1869 | 3091 | 2382 | 4,34 |
| 3 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,035 | 2,9 | 3,3 | 2,7 | 1,0 | n | 1 | 0,0843 | 0,0564 | 0,0749 | 0,0520 | 280 | 343 | 297 | 357 | 4,34 |
| 3 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,035 | 2,9 | 3,3 | 2,7 | 1,0 | n | 2 | 0,0843 | 0,0564 | 0,0749 | 0,0520 | 280 | 343 | 297 | 357 | 4,34 |
| 3 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,035 | 2,9 | 3,3 | 2,7 | 1,0 | n | 3 | 0,0843 | 0,0564 | 0,0749 | 0,0520 | 280 | 343 | 297 | 357 | 4,34 |
| 4 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,045 | 3,6 | 4,0 | 3,8 | 1,0 | s | 2 | 0,1393 | 0,0903 | 0,1087 | 0,0997 | 218 | 271 | 247 | 258 | 4,34 |
| 4 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,045 | 3,6 | 4,0 | 3,8 | 1,0 | s | 3 | 0,1393 | 0,0903 | 0,1087 | 0,0997 | 218 | 271 | 247 | 258 | 4,34 |
| 4 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 39 | 0,045 | 3,6 | 4,0 | 3,8 | 1,0 | n | 4 | 0,1393 | 0,0903 | 0,1087 | 0,0997 | 218 | 271 | 247 | 258 | 4,34 |
| 5 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 40 | 0,055 | 4,8 | 5,1 | 3,9 | 1,0 | s | 2 | 0,2081 | 0,1588 | 0,1805 | 0,1040 | 178 | 204 | 191 | 252 | 4,34 |
| 5 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 40 | 0,055 | 4,8 | 5,1 | 3,9 | 1,0 | s | 3 | 0,2081 | 0,1588 | 0,1805 | 0,1040 | 178 | 204 | 191 | 252 | 4,34 |
| 5 | 11/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,38 | 1,39 | 0,0447 | 40 | 0,055 | 4,8 | 5,1 | 3,9 | 1,0 | s | 4 | 0,2081 | 0,1588 | 0,1805 | 0,1040 | 178 | 204 | 191 | 252 | 4,34 |

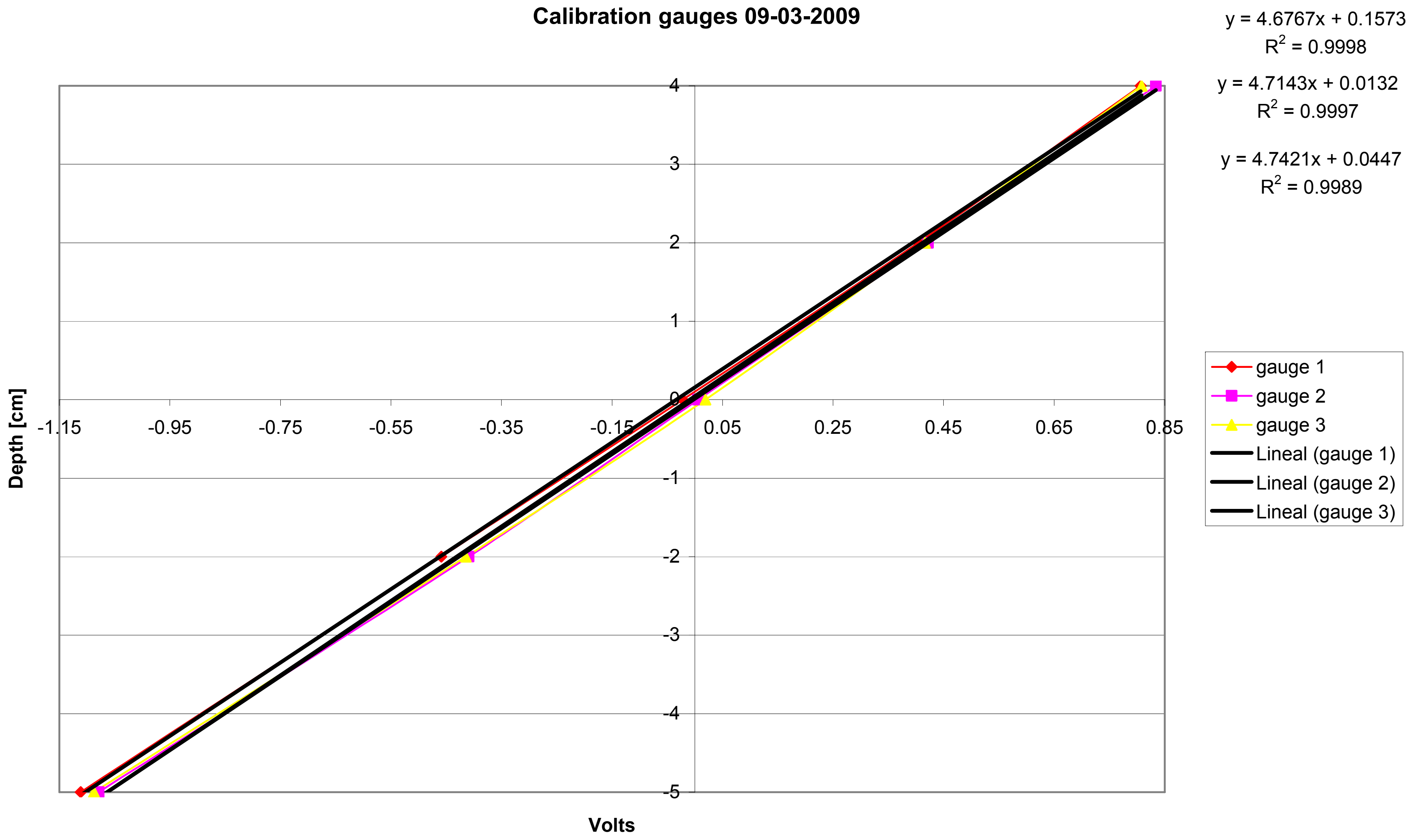
| CASE 9 | | STONES | | | SEDIMENT | | | | FLOW PROPERTIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test number | date | D [cm] | Number of layers | Material | Material | d [cm] | $s=\rho_s/\rho$ | d/D | Water depth [cm] | Hin [m] | $H_{g1}$ [cm] | $H_0$ [cm] | $H_{mes}$ [cm] | T [s] | Suction? Yes=s NO=n | hole number of the section | $\psi_{in}$ | $\psi_{g1}$ | $\psi_0$ | $\psi_{mes}$ | $A_{in}$ | $A_{g1}$ | $A_0$ | $A_{mes}$ | L to breaking [m] |
| | 12/05/2009 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,040 | 3,4 | 4,6 | 3,6 | 5,0 | n | 1 | 0,0013 | 0,0010 | 0,0017 | 0,0011 | 6131 | 7207 | 5385 | 6739 | 4,3 |
| 1 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,040 | 3,4 | 4,6 | 3,6 | 5,0 | n | 2 | 0,0013 | 0,0010 | 0,0017 | 0,0011 | 6131 | 7207 | 5385 | 6739 | 4,3 |
| 1 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,040 | 3,4 | 4,6 | 3,6 | 5,0 | n | 3 | 0,0013 | 0,0010 | 0,0017 | 0,0011 | 6131 | 7207 | 5385 | 6739 | 4,3 |
| 2 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,060 | 5,0 | 6,1 | 6,0 | 5,0 | n | 1 | 0,0030 | 0,0021 | 0,0031 | 0,0030 | 4088 | 4897 | 3990 | 4083 | 4,3 |
| 2 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,060 | 5,0 | 6,1 | 6,0 | 5,0 | n | 2 | 0,0030 | 0,0021 | 0,0031 | 0,0030 | 4088 | 4897 | 3990 | 4083 | 4,3 |
| 2 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,060 | 5,0 | 6,1 | 6,0 | 5,0 | n | 3 | 0,0030 | 0,0021 | 0,0031 | 0,0030 | 4088 | 4897 | 3990 | 4083 | 4,3 |
| 3 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,080 | 7,1 | 7,5 | 6,5 | 5,0 | n | 1 | 0,0053 | 0,0041 | 0,0046 | 0,0035 | 3066 | 3466 | 3268 | 3786 | 4,3 |
| 3 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,080 | 7,1 | 7,5 | 6,5 | 5,0 | n | 2 | 0,0053 | 0,0041 | 0,0046 | 0,0035 | 3066 | 3466 | 3268 | 3786 | 4,3 |
| 3 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,080 | 7,1 | 7,5 | 6,5 | 5,0 | n | 3 | 0,0053 | 0,0041 | 0,0046 | 0,0035 | 3066 | 3466 | 3268 | 3786 | 4,3 |
| 4 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 41 | 0,090 | 7,3 | 7,4 | 8,0 | 5,0 | n | 2 | 0,0067 | 0,0044 | 0,0045 | 0,0053 | 2725 | 3340 | 3308 | 3051 | 4,3 |
| 4 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 41 | 0,090 | 7,3 | 7,4 | 8,0 | 5,0 | n | 3 | 0,0067 | 0,0044 | 0,0045 | 0,0053 | 2725 | 3340 | 3308 | 3051 | 4,3 |
| 4 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 41 | 0,090 | 7,3 | 7,4 | 8,0 | 5,0 | n | 4 | 0,0067 | 0,0044 | 0,0045 | 0,0053 | 2725 | 3340 | 3308 | 3051 | 4,3 |
| 5 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 41 | 0,110 | 8,5 | 8,9 | 8,3 | 5,0 | s | 2 | 0,0100 | 0,0060 | 0,0065 | 0,0056 | 2230 | 2885 | 2770 | 2964 | 4,3 |
| 5 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 41 | 0,110 | 8,5 | 8,9 | 8,3 | 5,0 | n | 3 | 0,0100 | 0,0060 | 0,0065 | 0,0056 | 2230 | 2885 | 2770 | 2964 | 4,3 |
| 5 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 41 | 0,110 | 8,5 | 8,9 | 8,3 | 5,0 | n | 4 | 0,0100 | 0,0060 | 0,0065 | 0,0056 | 2230 | 2885 | 2770 | 2964 | 4,3 |
| 6 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 41,5 | 0,130 | 9,7 | 9,8 | 9,1 | 5,0 | s | 2 | 0,0139 | 0,0077 | 0,0079 | 0,0068 | 1887 | 2539 | 2502 | 2690 | 4,3 |
| 6 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 41,5 | 0,130 | 9,7 | 9,8 | 9,1 | 5,0 | n | 3 | 0,0139 | 0,0077 | 0,0079 | 0,0068 | 1887 | 2539 | 2502 | 2690 | 4,3 |

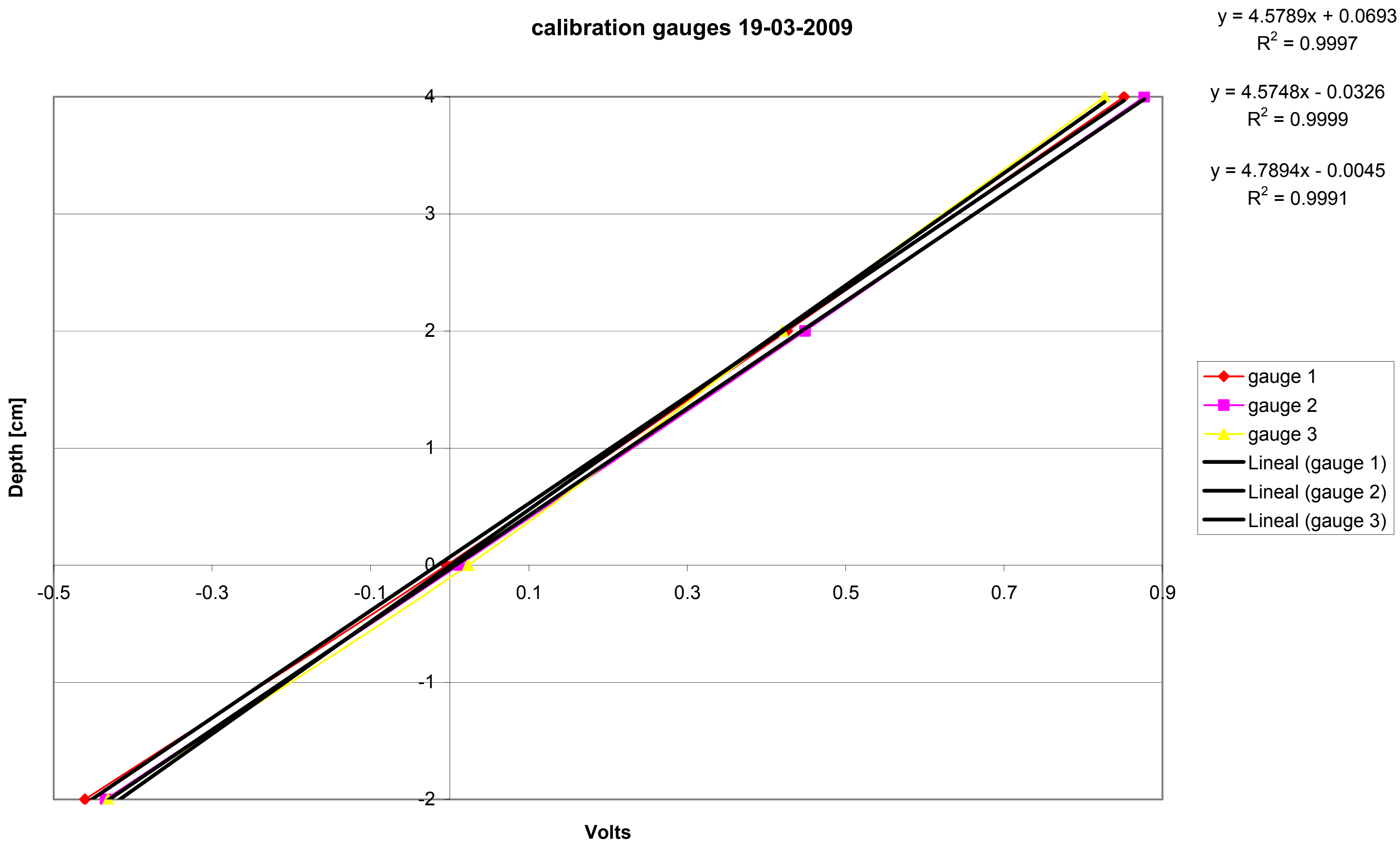
| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 41,5 | 0,130 | 9,7 | 9,8 | 9,1 | 5,0 | n | 4 | 0,0139 | 0,0077 | 0,0079 | 0,0068 | 1887 | 2539 | 2502 | 2690 | 4,3 |
| 7 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,060 | 6,4 | 4,1 | 6,0 | 3,0 | n | 2 | 0,0082 | 0,0095 | 0,0039 | 0,0083 | 1472 | 1372 | 2134 | 1468 | 4,2 |
| 7 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,060 | 6,4 | 4,1 | 6,0 | 3,0 | n | 3 | 0,0082 | 0,0095 | 0,0039 | 0,0083 | 1472 | 1372 | 2134 | 1468 | 4,2 |
| 7 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,060 | 6,4 | 4,1 | 6,0 | 3,0 | n | 4 | 0,0082 | 0,0095 | 0,0039 | 0,0083 | 1472 | 1372 | 2134 | 1468 | 4,2 |
| 8 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,070 | 6,9 | 5,0 | 7,8 | 3,0 | n | 1 | 0,0112 | 0,0109 | 0,0056 | 0,0138 | 1261 | 1282 | 1782 | 1136 | 4,2 |
| 8 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,070 | 6,9 | 5,0 | 7,8 | 3,0 | s | 3 | 0,0112 | 0,0109 | 0,0056 | 0,0138 | 1261 | 1282 | 1782 | 1136 | 4,2 |
| 8 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,070 | 6,9 | 5,0 | 7,8 | 3,0 | n | 4 | 0,0112 | 0,0109 | 0,0056 | 0,0138 | 1261 | 1282 | 1782 | 1136 | 4,2 |
| 9 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40 | 0,090 | 9,2 | 6,9 | 10,2 | 3,0 | s | 1 | 0,0185 | 0,0195 | 0,0109 | 0,0238 | 981 | 957 | 1282 | 866 | 4,2 |
| 9 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40 | 0,090 | 9,2 | 6,9 | 10,2 | 3,0 | s | 3 | 0,0185 | 0,0195 | 0,0109 | 0,0238 | 981 | 957 | 1282 | 866 | 4,2 |
| 9 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40 | 0,090 | 9,2 | 6,9 | 10,2 | 3,0 | n | 4 | 0,0185 | 0,0195 | 0,0109 | 0,0238 | 981 | 957 | 1282 | 866 | 4,2 |
| 10 | 05/12/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40 | 0,100 | 10,1 | 7,8 | 11,0 | 3,0 | s | 2 | 0,0229 | 0,0235 | 0,0140 | 0,0278 | 883 | 871 | 1129 | 801 | 4,2 |
| 10 | 05/12/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40 | 0,100 | 10,1 | 7,8 | 11,0 | 3,0 | s | 3 | 0,0229 | 0,0235 | 0,0140 | 0,0278 | 883 | 871 | 1129 | 801 | 4,2 |
| 10 | 05/12/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40 | 0,100 | 10,1 | 7,8 | 11,0 | 3,0 | s | 4 | 0,0229 | 0,0235 | 0,0140 | 0,0278 | 883 | 871 | 1129 | 801 | 4,2 |
| 11 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,070 | 5,5 | 5,9 | 5,6 | 1,0 | n | 1 | 0,1009 | 0,0621 | 0,0711 | 0,0649 | 140 | 179 | 167 | 175 | 4,2 |
| 11 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,070 | 5,5 | 5,9 | 5,6 | 1,0 | n | 3 | 0,1009 | 0,0621 | 0,0711 | 0,0649 | 140 | 179 | 167 | 175 | 4,2 |
| 11 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,070 | 5,5 | 5,9 | 5,6 | 1,0 | n | 4 | 0,1009 | 0,0621 | 0,0711 | 0,0649 | 140 | 179 | 167 | 175 | 4,2 |
| 12 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,090 | 6,8 | 7,2 | 7,0 | 1,0 | n | 1 | 0,1668 | 0,0958 | 0,1058 | 0,1009 | 109 | 144 | 137 | 140 | 4,2 |
| 12 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,090 | 6,8 | 7,2 | 7,0 | 1,0 | n | 3 | 0,1668 | 0,0958 | 0,1058 | 0,1009 | 109 | 144 | 137 | 140 | 4,2 |
| 12 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 39 | 0,090 | 6,8 | 7,2 | 7,0 | 1,0 | n | 4 | 0,1668 | 0,0958 | 0,1058 | 0,1009 | 109 | 144 | 137 | 140 | 4,2 |
| 13 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40 | 0,120 | 9,4 | 9,7 | 8,1 | 1,0 | n | 2 | 0,2965 | 0,1816 | 0,1944 | 0,1339 | 82 | 104 | 101 | 122 | 4,2 |
| 13 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40 | 0,120 | 9,4 | 9,7 | 8,1 | 1,0 | n | 3 | 0,2965 | 0,1816 | 0,1944 | 0,1339 | 82 | 104 | 101 | 122 | 4,2 |
| 13 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40 | 0,120 | 9,4 | 9,7 | 8,1 | 1,0 | n | 4 | 0,2965 | 0,1816 | 0,1944 | 0,1339 | 82 | 104 | 101 | 122 | 4,2 |
| 14 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40,5 | 0,130 | 10,2 | 9,9 | 8,1 | 1,0 | n | 1 | 0,3480 | 0,2160 | 0,2031 | 0,1339 | 75 | 96 | 99 | 122 | 4,2 |
| 14 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40,5 | 0,130 | 10,2 | 9,9 | 8,1 | 1,0 | n | 3 | 0,3480 | 0,2160 | 0,2031 | 0,1339 | 75 | 96 | 99 | 122 | 4,2 |
| 14 | 12/05/2009 | 8,5 | 1 | Natural stones | Particles | 0,3 | 2,65 | 0,0353 | 40,5 | 0,130 | 10,2 | 9,9 | 8,1 | 1,0 | n | 4 | 0,3480 | 0,2160 | 0,2031 | 0,1339 | 75 | 96 | 99 | 122 | 4,2 |

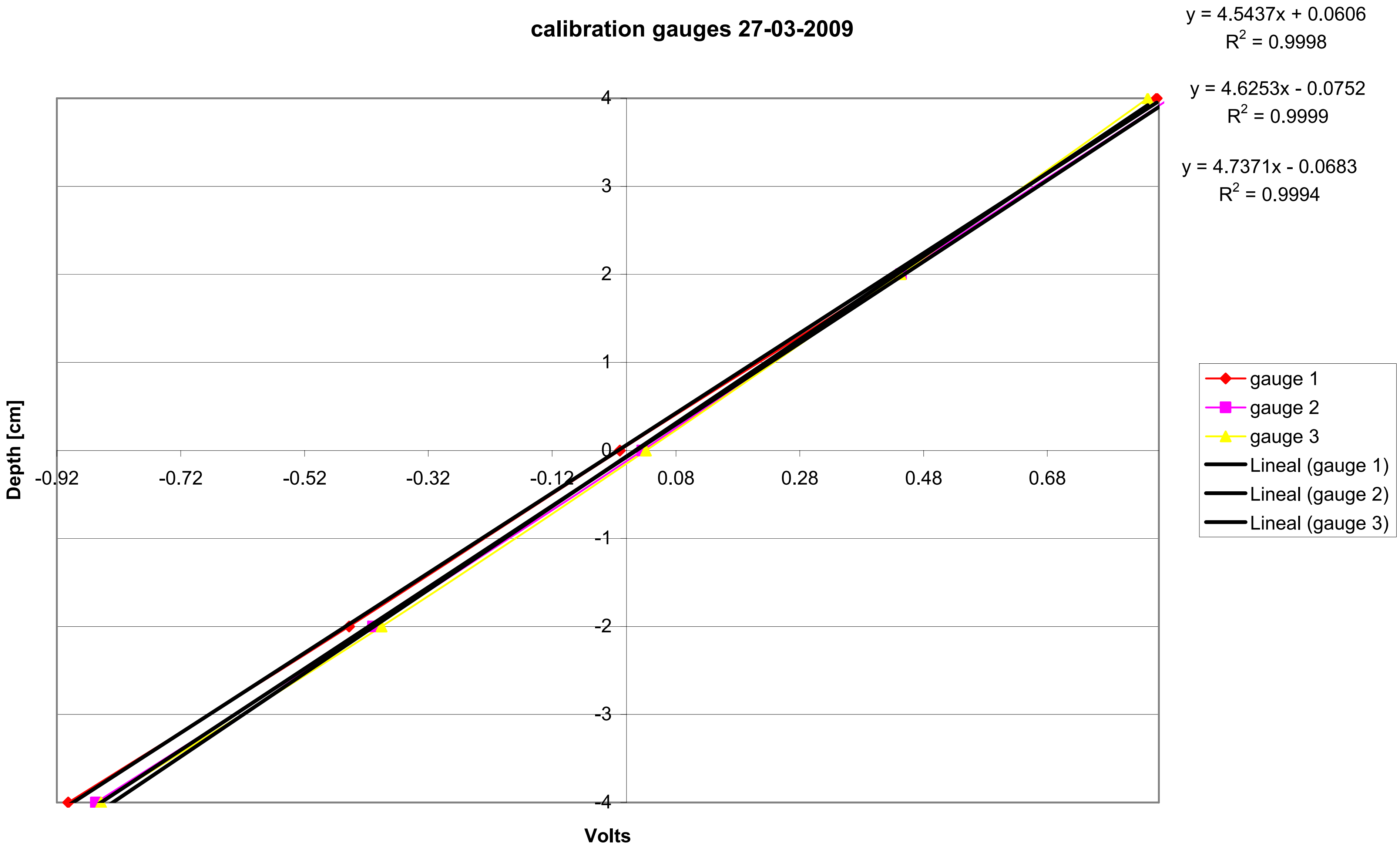
| CASE 10 | | STONES | | | SEDIMENT | | | | FLOW PROPERTIES | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test number | date | D [cm] | Number of layers | Material | Material | d [cm] | $s=\rho_s/\rho$ | d/D | Water depth [cm] | Hin [m] | $H_{g1}$ [cm] | $H_0$ [cm] | $H_{mes}$ [cm] | T [s] | Suction? Yes=s NO=n | hole number of the section | $\psi_{in}$ | $\psi_{g1}$ | $\psi_0$ | $\psi_{mes}$ | $A_{in}$ | $A_{g1}$ | $A_0$ | $A_{mes}$ | L to breaking [m] |
| | 14/4/2009 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,7 | 0,035 | 2,8 | 2,7 | 1,9 | 1,0 | n | 1 | 0,0541 | 0,0351 | 0,0322 | 0,0161 | 280 | 348 | 363 | 513 | 4,27 |
| 1 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,7 | 0,035 | 2,8 | 2,7 | 1,9 | 1,0 | n | 2 | 0,0541 | 0,0351 | 0,0322 | 0,0161 | 280 | 348 | 363 | 513 | 4,27 |
| 1 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,7 | 0,035 | 2,8 | 2,7 | 1,9 | 1,0 | n | 3 | 0,0541 | 0,0351 | 0,0322 | 0,0161 | 280 | 348 | 363 | 513 | 4,27 |
| 2 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 40 | 0,050 | 4,2 | 3,5 | 3,5 | 1,0 | n | 1 | 0,1103 | 0,0763 | 0,0528 | 0,0533 | 196 | 236 | 284 | 282 | 4,27 |
| 2 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 40 | 0,050 | 4,2 | 3,5 | 3,5 | 1,0 | n | 2 | 0,1103 | 0,0763 | 0,0528 | 0,0533 | 196 | 236 | 284 | 282 | 4,27 |
| 2 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 40 | 0,050 | 4,2 | 3,5 | 3,5 | 1,0 | n | 3 | 0,1103 | 0,0763 | 0,0528 | 0,0533 | 196 | 236 | 284 | 282 | 4,27 |
| 3 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 40,5 | 0,070 | 5,7 | 5,9 | 5,7 | 1,1 | n | 1 | 0,1787 | 0,1205 | 0,1270 | 0,1177 | 170 | 206 | 201 | 209 | 4,27 |
| 3 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 40,5 | 0,070 | 5,7 | 5,9 | 5,7 | 1,1 | n | 2 | 0,1787 | 0,1205 | 0,1270 | 0,1177 | 170 | 206 | 201 | 209 | 4,27 |
| 3 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 40,5 | 0,070 | 5,7 | 5,9 | 5,7 | 1,1 | n | 3 | 0,1787 | 0,1205 | 0,1270 | 0,1177 | 170 | 206 | 201 | 209 | 4,27 |
| 4 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 40,5 | 0,080 | 6,4 | 6,5 | 6,4 | 1,1 | n | 1 | 0,2334 | 0,1486 | 0,1549 | 0,1473 | 148 | 186 | 182 | 187 | 4,27 |
| 4 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 40,5 | 0,080 | 6,4 | 6,5 | 6,4 | 1,1 | n | 2 | 0,2334 | 0,1486 | 0,1549 | 0,1473 | 148 | 186 | 182 | 187 | 4,27 |
| 4 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 40,5 | 0,080 | 6,4 | 6,5 | 6,4 | 1,1 | n | 3 | 0,2334 | 0,1486 | 0,1549 | 0,1473 | 148 | 186 | 182 | 187 | 4,27 |
| 5 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 41,5 | 0,095 | 7,6 | 8,2 | 7,0 | 1,1 | n | 1 | 0,3291 | 0,2112 | 0,2431 | 0,1794 | 125 | 156 | 145 | 169 | 4,27 |
| 5 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 41,5 | 0,095 | 7,6 | 8,2 | 7,0 | 1,1 | n | 2 | 0,3291 | 0,2112 | 0,2431 | 0,1794 | 125 | 156 | 145 | 169 | 4,27 |
| 5 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 41,5 | 0,095 | 7,6 | 8,2 | 7,0 | 1,1 | s | 3 | 0,3291 | 0,2112 | 0,2431 | 0,1794 | 125 | 156 | 145 | 169 | 4,27 |
| 6 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 42,3 | 0,105 | 8,5 | 9,1 | 7,6 | 1,1 | n | 1 | 0,4021 | 0,2647 | 0,3053 | 0,2096 | 113 | 139 | 130 | 157 | 4,28 |
| 6 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 42,3 | 0,105 | 8,5 | 9,1 | 7,6 | 1,1 | n | 2 | 0,4021 | 0,2647 | 0,3053 | 0,2096 | 113 | 139 | 130 | 157 | 4,28 |
| 6 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 42,3 | 0,105 | 8,5 | 9,1 | 7,6 | 1,1 | s | 3 | 0,4021 | 0,2647 | 0,3053 | 0,2096 | 113 | 139 | 130 | 157 | 4,28 |
| 7 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 42,3 | 0,125 | 9,4 | 10,2 | 6,6 | 1,2 | s | 1 | 0,4788 | 0,2680 | 0,3169 | 0,1323 | 113 | 151 | 139 | 215 | 4,28 |
| 7 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 42,3 | 0,125 | 9,4 | 10,2 | 6,6 | 1,2 | n | 2 | 0,4788 | 0,2680 | 0,3169 | 0,1323 | 113 | 151 | 139 | 215 | 4,28 |
| 7 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 42,3 | 0,125 | 9,4 | 10,2 | 6,6 | 1,2 | s | 3 | 0,4788 | 0,2680 | 0,3169 | 0,1323 | 113 | 151 | 139 | 215 | 4,28 |
| 8 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 43,3 | 0,140 | 11,6 | 10,7 | 8,1 | 1,3 | s | 1 | 0,5118 | 0,3540 | 0,2986 | 0,1698 | 118 | 142 | 155 | 206 | 4,28 |
| 8 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 43,3 | 0,140 | 11,6 | 10,7 | 8,1 | 1,3 | s | 2 | 0,5118 | 0,3540 | 0,2986 | 0,1698 | 118 | 142 | 155 | 206 | 4,28 |
| 8 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 43,3 | 0,140 | 11,6 | 10,7 | 8,1 | 1,3 | s | 3 | 0,5118 | 0,3540 | 0,2986 | 0,1698 | 118 | 142 | 155 | 206 | 4,28 |

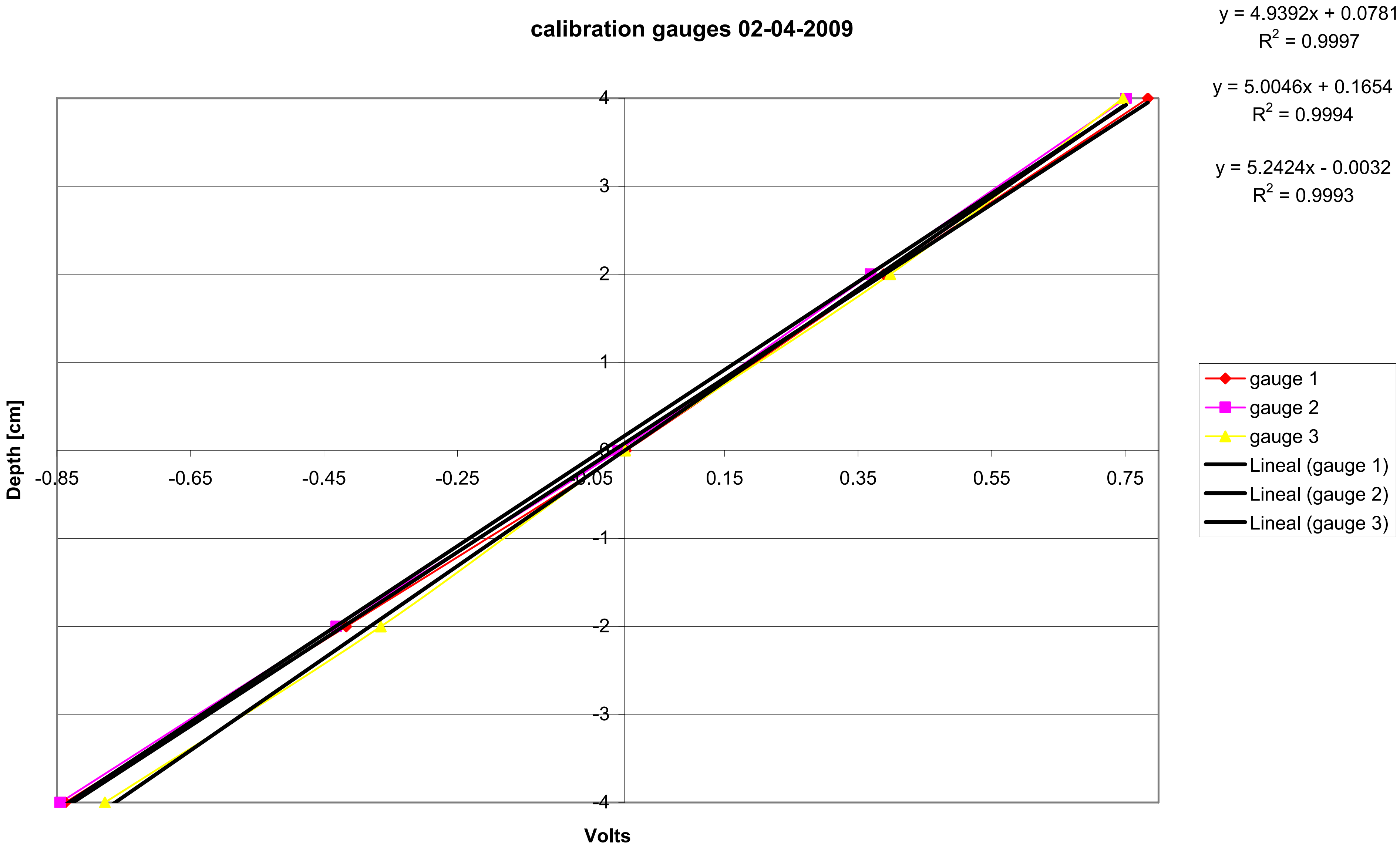
| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,030 | 3,3 | 1,7 | 3,3 | 3,0 | n | 1 | 0,0044 | 0,0053 | 0,0014 | 0,0055 | 2943 | 2693 | 5248 | 2642 | 4,25 |
| 9 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,030 | 3,3 | 1,7 | 3,3 | 3,0 | n | 2 | 0,0044 | 0,0053 | 0,0014 | 0,0055 | 2943 | 2693 | 5248 | 2642 | 4,25 |
| 9 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,030 | 3,3 | 1,7 | 3,3 | 3,0 | n | 3 | 0,0044 | 0,0053 | 0,0014 | 0,0055 | 2943 | 2693 | 5248 | 2642 | 4,25 |
| 10 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,050 | 4,8 | 3,4 | 5,5 | 3,0 | n | 1 | 0,0123 | 0,0112 | 0,0055 | 0,0146 | 1766 | 1846 | 2625 | 1618 | 4,25 |
| 10 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,050 | 4,8 | 3,4 | 5,5 | 3,0 | s | 2 | 0,0123 | 0,0112 | 0,0055 | 0,0146 | 1766 | 1846 | 2625 | 1618 | 4,25 |
| 10 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,050 | 4,8 | 3,4 | 5,5 | 3,0 | n | 3 | 0,0123 | 0,0112 | 0,0055 | 0,0146 | 1766 | 1846 | 2625 | 1618 | 4,25 |
| 11 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,060 | 5,7 | 4,5 | 6,6 | 3,0 | s | 1 | 0,0177 | 0,0160 | 0,0097 | 0,0216 | 1472 | 1544 | 1982 | 1331 | 4,25 |
| 11 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,060 | 5,7 | 4,5 | 6,6 | 3,0 | s | 2 | 0,0177 | 0,0160 | 0,0097 | 0,0216 | 1472 | 1544 | 1982 | 1331 | 4,25 |
| 11 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,060 | 5,7 | 4,5 | 6,6 | 3,0 | s | 3 | 0,0177 | 0,0160 | 0,0097 | 0,0216 | 1472 | 1544 | 1982 | 1331 | 4,25 |
| 12 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,030 | 2,6 | 3,9 | 4,9 | 5,0 | n | 1 | 0,0016 | 0,0012 | 0,0027 | 0,0042 | 8175 | 9473 | 6259 | 5004 | 4,25 |
| 12 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,030 | 2,6 | 3,9 | 4,9 | 5,0 | n | 2 | 0,0016 | 0,0012 | 0,0027 | 0,0042 | 8175 | 9473 | 6259 | 5004 | 4,25 |
| 12 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,030 | 2,6 | 3,9 | 4,9 | 5,0 | n | 3 | 0,0016 | 0,0012 | 0,0027 | 0,0042 | 8175 | 9473 | 6259 | 5004 | 4,25 |
| 13 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,040 | 3,5 | 5,4 | 4,9 | 5,0 | s | 1 | 0,0028 | 0,0021 | 0,0052 | 0,0043 | 6131 | 7084 | 4523 | 4967 | 4,25 |
| 13 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,040 | 3,5 | 5,4 | 4,9 | 5,0 | n | 2 | 0,0028 | 0,0021 | 0,0052 | 0,0043 | 6131 | 7084 | 4523 | 4967 | 4,25 |
| 13 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,040 | 3,5 | 5,4 | 4,9 | 5,0 | n | 3 | 0,0028 | 0,0021 | 0,0052 | 0,0043 | 6131 | 7084 | 4523 | 4967 | 4,25 |
| 14 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,050 | 4,0 | 6,0 | 6,0 | 5,0 | s | 1 | 0,0044 | 0,0029 | 0,0064 | 0,0063 | 4905 | 6068 | 4061 | 4108 | 4,25 |
| 14 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,050 | 4,0 | 6,0 | 6,0 | 5,0 | n | 2 | 0,0044 | 0,0029 | 0,0064 | 0,0063 | 4905 | 6068 | 4061 | 4108 | 4,25 |
| 14 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,050 | 4,0 | 6,0 | 6,0 | 5,0 | s | 3 | 0,0044 | 0,0029 | 0,0064 | 0,0063 | 4905 | 6068 | 4061 | 4108 | 4,25 |
| 15 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,060 | 4,8 | 6,9 | 6,0 | 5,0 | s | 1 | 0,0064 | 0,0041 | 0,0085 | 0,0064 | 4088 | 5090 | 3542 | 4070 | 4,25 |
| 15 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,060 | 4,8 | 6,9 | 6,0 | 5,0 | s | 2 | 0,0064 | 0,0041 | 0,0085 | 0,0064 | 4088 | 5090 | 3542 | 4070 | 4,25 |
| 15 | 14/4/2009 | 8,5 | 1 | Natural stones | Particles | 0,14 | 2,65 | 0,0165 | 38,4 | 0,060 | 4,8 | 6,9 | 6,0 | 5,0 | s | 3 | 0,0064 | 0,0041 | 0,0085 | 0,0064 | 4088 | 5090 | 3542 | 4070 | 4,25 |

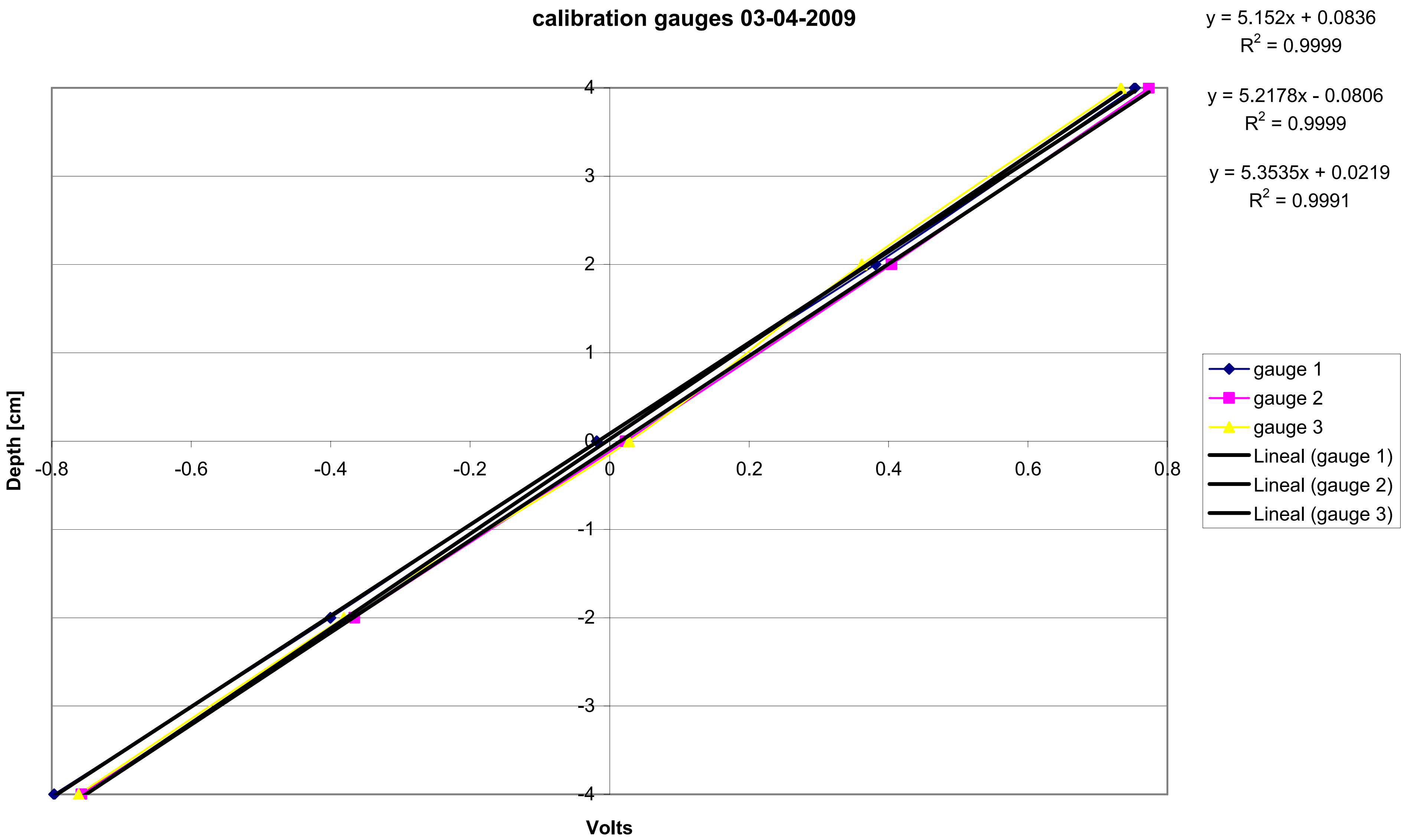
# APPENDIX B

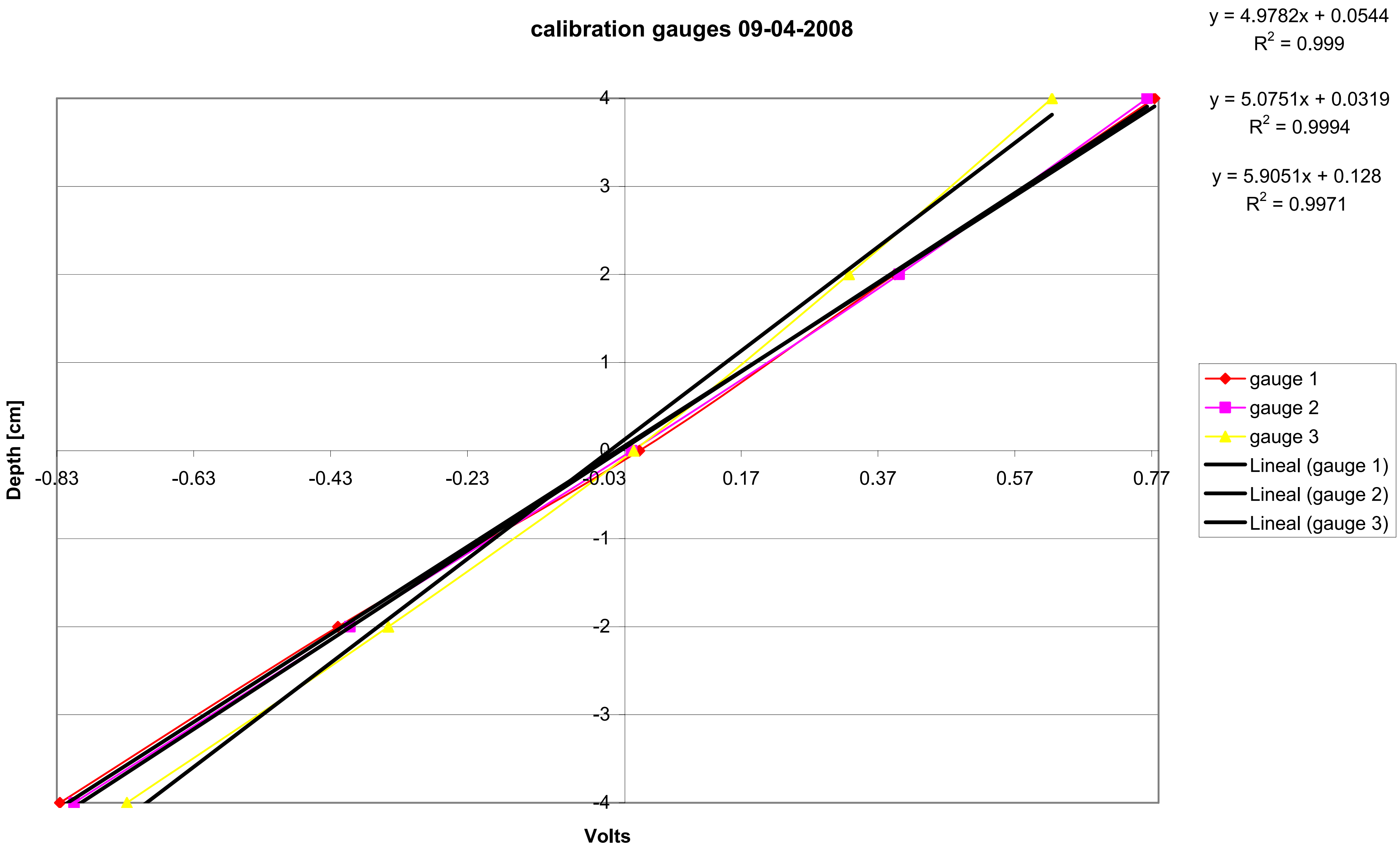

Calibration gauges 09-03-2009
y = 4.6767x + 0.1573
R2 = 0.9998
y = 4.7143x + 0.0132
R2 = 0.9997
y = 4.7421x + 0.0447
R2 = 0.9989
Depth [cm]
Volts
-1.15
-0.95
-0.75
-0.55
-0.35
-0.15
0.05
0.25
0.45
0.65
0.85
4
3
2
1
0
-1
-2
-3
-4
-5
gauge 1
gauge 2
gauge 3
Lineal (gauge 1)
Lineal (gauge 2)
Lineal (gauge 3)

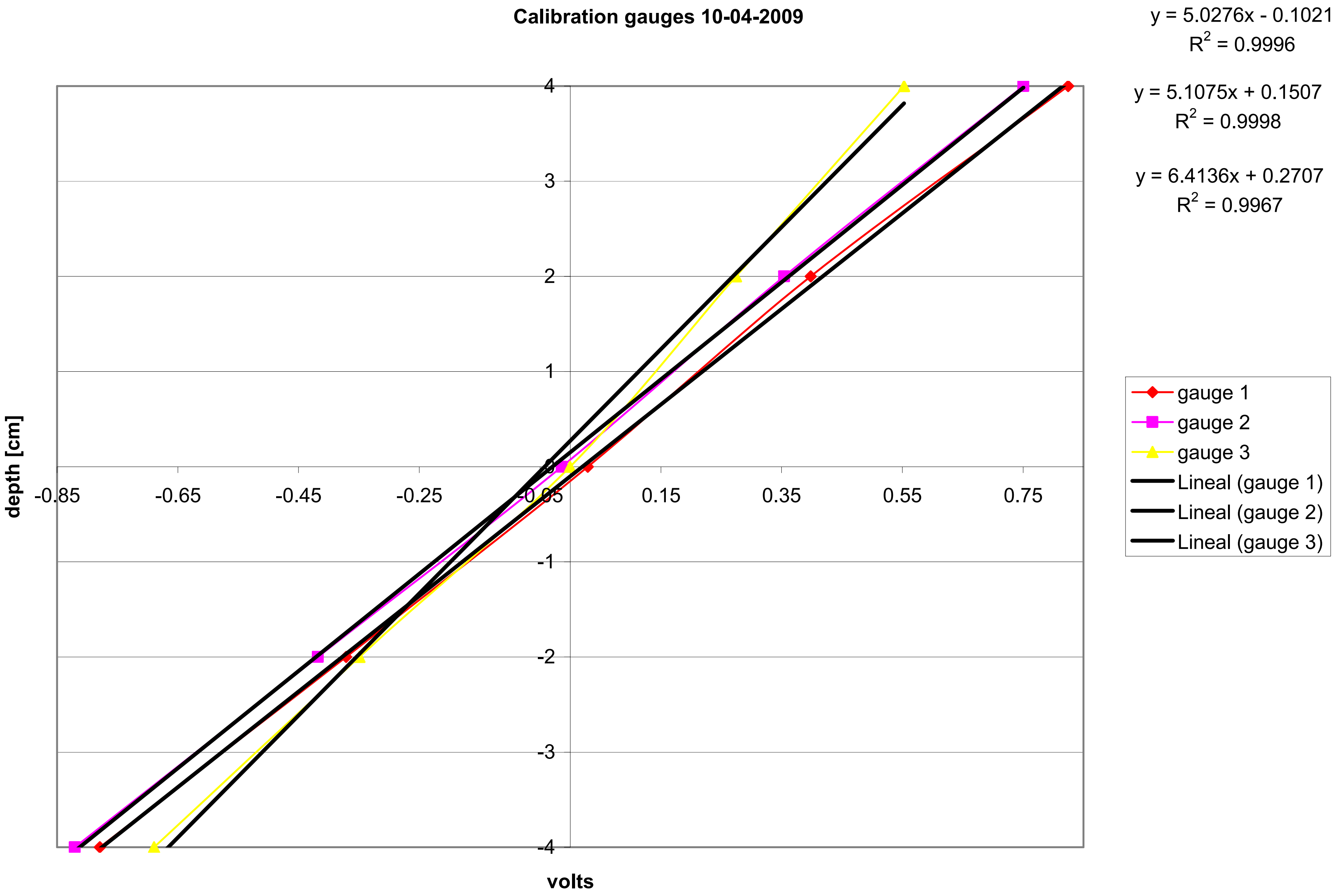

calibration gauges 19-03-2009
y = 4.5789x + 0.0693
R2 = 0.9997
y = 4.5748x - 0.0326
R2 = 0.9999
y = 4.7894x - 0.0045
R2 = 0.9991
Depth [cm]
Volts
4
3
2
1
0
-1
-2
-0.5
-0.3
-0.1
0.1
0.3
0.5
0.7
0.9
gauge 1
gauge 2
gauge 3
Lineal (gauge 1)
Lineal (gauge 2)
Lineal (gauge 3)


calibration gauges 27-03-2009
y = 4.5437x + 0.0606
R2 = 0.9998
y = 4.6253x - 0.0752
R2 = 0.9999
y = 4.7371x - 0.0683
R2 = 0.9994
Depth [cm]
Volts
-0.92
-0.72
-0.52
-0.32
-0.12
0.08
0.28
0.48
0.68
4
3
2
1
0
-1
-2
-3
-4
gauge 1
gauge 2
gauge 3
Lineal (gauge 1)
Lineal (gauge 2)
Lineal (gauge 3)

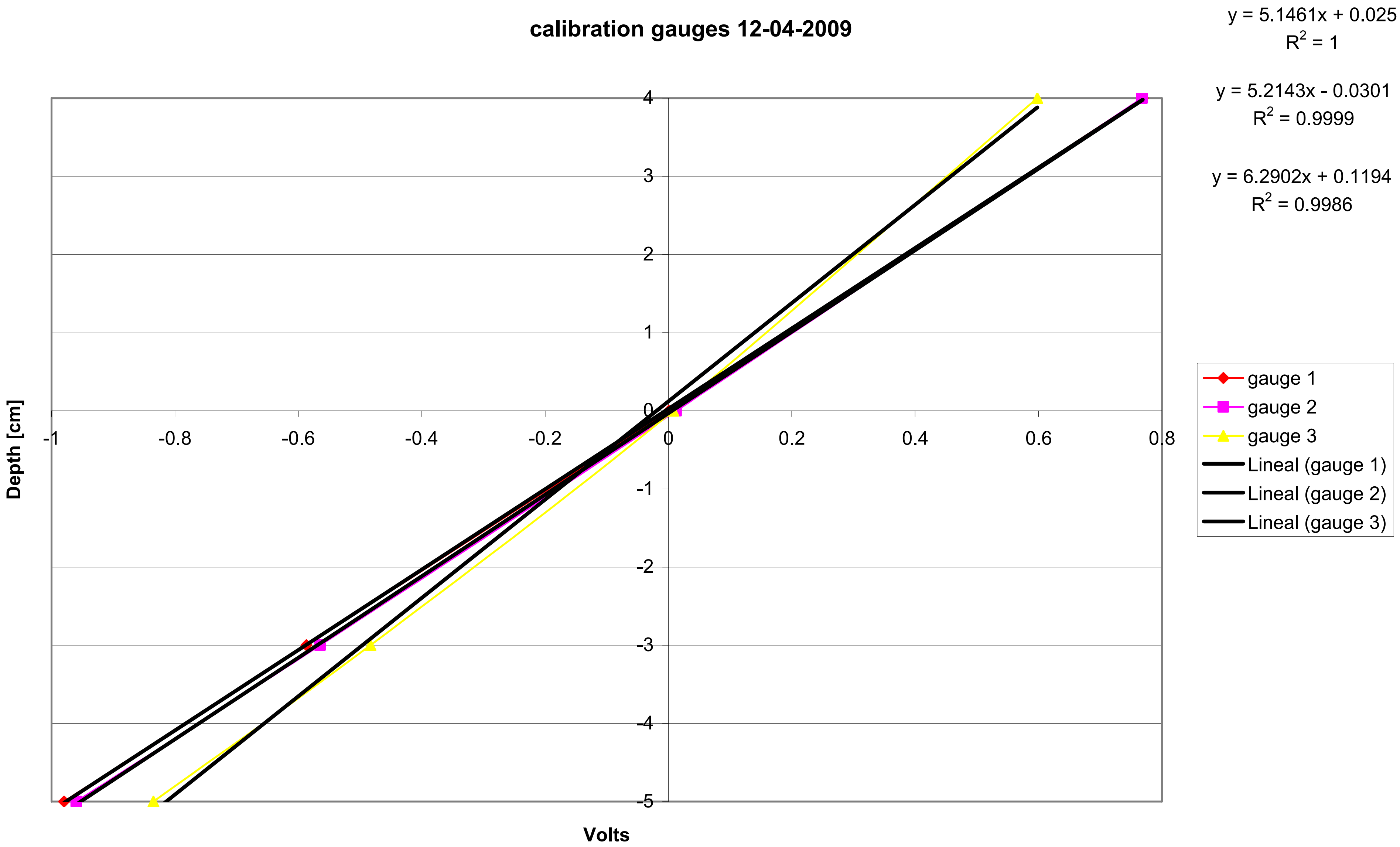

calibration gauges 02-04-2009
y = 4.9392x + 0.0781
$R^2$ = 0.9997
y = 5.0046x + 0.1654
$R^2$ = 0.9994
y = 5.2424x - 0.0032
$R^2$ = 0.9993
Depth [cm]
Volts
4
3
2
1
0
-1
-2
-3
-4
-0.85
-0.65
-0.45
-0.25
-0.05
0.15
0.35
0.55
0.75
gauge 1
gauge 2
gauge 3
Lineal (gauge 1)
Lineal (gauge 2)
Lineal (gauge 3)

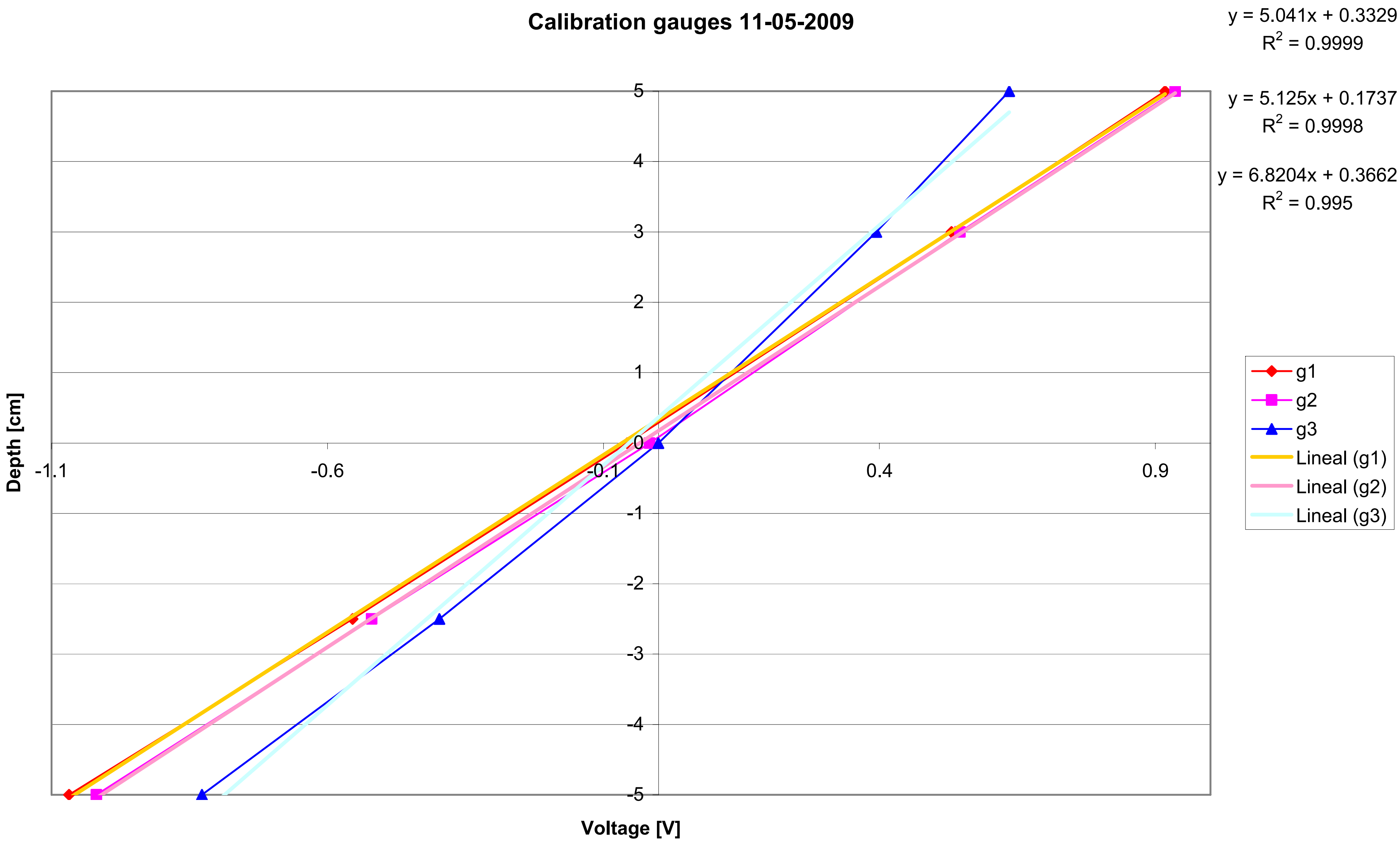

calibration gauges 03-04-2009
y = 5.152x + 0.0836
R2 = 0.9999
y = 5.2178x - 0.0806
R2 = 0.9999
y = 5.3535x + 0.0219
R2 = 0.9991
Depth [cm]
Volts
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
4
3
2
1
0
-1
-2
-3
-4
gauge 1
gauge 2
gauge 3
Lineal (gauge 1)
Lineal (gauge 2)
Lineal (gauge 3)


calibration gauges 09-04-2008
y = 4.9782x + 0.0544
$R^2$ = 0.999
y = 5.0751x + 0.0319
$R^2$ = 0.9994
y = 5.9051x + 0.128
$R^2$ = 0.9971
Depth [cm]
4
3
2
1
0
-1
-2
-3
-4
-0.83
-0.63
-0.43
-0.23
-0.03
0.17
0.37
0.57
0.77
Volts
gauge 1
gauge 2
gauge 3
Lineal (gauge 1)
Lineal (gauge 2)
Lineal (gauge 3)

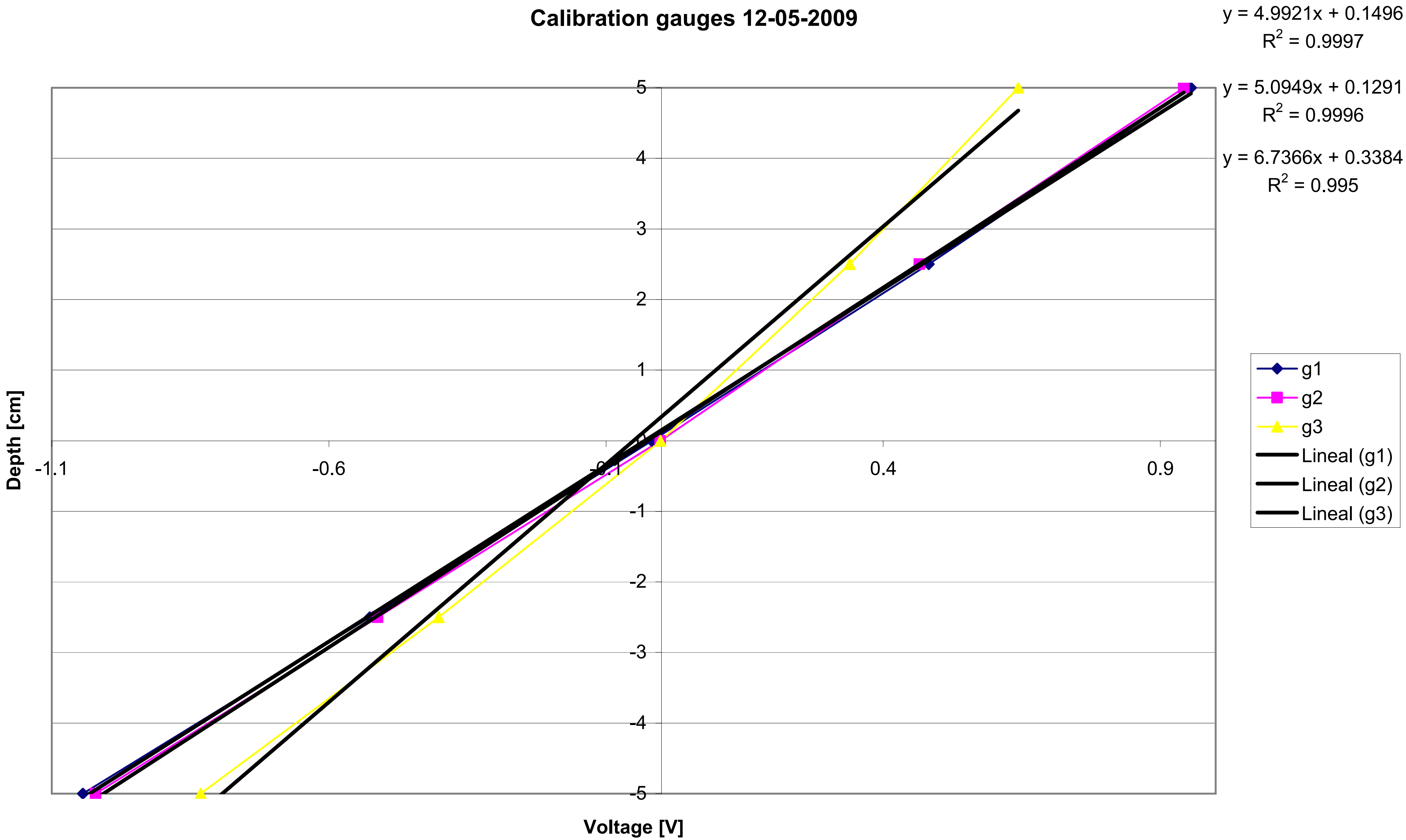


Calibration gauges 10-04-2009
y = 5.0276x - 0.1021
R2 = 0.9996
y = 5.1075x + 0.1507
R2 = 0.9998
y = 6.4136x + 0.2707
R2 = 0.9967
4
3
2
1
0
-1
-2
-3
-4
-0.85
-0.65
-0.45
-0.25
-0.05
0.15
0.35
0.55
0.75
depth [cm]
volts
gauge 1
gauge 2
gauge 3
Lineal (gauge 1)
Lineal (gauge 2)
Lineal (gauge 3)


calibration gauges 12-04-2009
y = 5.1461x + 0.025
R2 = 1
y = 5.2143x - 0.0301
R2 = 0.9999
y = 6.2902x + 0.1194
R2 = 0.9986
Depth [cm]
Volts
4
3
2
1
0
-1
-2
-3
-4
-5
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
gauge 1
gauge 2
gauge 3
Lineal (gauge 1)
Lineal (gauge 2)
Lineal (gauge 3)



Calibration gauges 11-05-2009
y = 5.041x + 0.3329
R2 = 0.9999
y = 5.125x + 0.1737
R2 = 0.9998
y = 6.8204x + 0.3662
R2 = 0.995
Depth [cm]
Voltage [V]
5
4
3
2
1
0
-1
-2
-3
-4
-5
-1.1
-0.6
-0.1
0.4
0.9
g1
g2
g3
Lineal (g1)
Lineal (g2)
Lineal (g3)



Calibration gauges 12-05-2009
y = 4.9921x + 0.1496
R2 = 0.9997
y = 5.0949x + 0.1291
R2 = 0.9996
y = 6.7366x + 0.3384
R2 = 0.995
5
4
3
2
1
-1
-2
-3
-4
-5
-1.1
-0.6
-0.1
0.4
0.9
Depth [cm]
Voltage [V]
g1
g2
g3
Lineal (g1)
Lineal (g2)
Lineal (g3)